PAPERS

ON SUBJECTS CONNECTED WITH

THE DUTIES

OF THE

CORPS OF ROYAL ENGINEERS,

CONTRIBUTED BY

OFFICERS OF THE ROYAL ENGINEERS.

NEW SERIES.

VOL. XV.

PRINTED BY JACKSON & SON, WOOLWICH.

1866.

PREFACE.

Since the issue of the last Volume, the Occasional Meetings for Discussions have been continued at the War Office, and some of the Papers read, and the discussions which took place, will be found in the present Volume.

With the exception of the experiments against the casemate at Shoeburyness, none of sufficient interest have occurred there, since Captain Inglis' paper, in Vol. XIV, to require a special record in this Volume. Official reasons against the publication of the results of the experiments above alluded to existed until too late to admit of their being printed this year; they will consequently appear in Vol. XVI.

The thanks of the Corps are due to Henry Cole, Esq., C.B., for his Memoir of the late Captain Fowke, R.E.; and to S. B. Howlett, Esq., Professor Abel, F.R.S., and Major Miller, R.A., V.C., for the Papers contributed by them.

Papers for Vol. XVI, for discussion or otherwise, will be now gladly received. It may be well to remind the Corps that the subject of the Influence of Rifled Ordnance on the Attack and Defence of Fortresses, has, as yet, been treated on only as far as the 1st parallel.

C. S. HUTCHINSON,
Captain, Royal Engineers,
Editor.

Woolwich Common,
November 1866.

CONTENTS.

LIST OF PLATES.

BRIEF NOTES

ON THE CAREER OF THE LATE

CAPTAIN FRANCIS FOWKE, R.E.,

By HENRY COLE, C.B.

The Corps Papers of the most scientific branch of the British Army are so suitable a place to preserve some notice of the career of one of the most scientific members of that corps, that I have cheerfully acceded to the request made to me to note down some of the facts of the life of Captain Francis Fowke, R.E., with whom I had been almost in daily intercourse since the year 1854.

He was descended from an old Leicestershire family; born in Belfast in July, 1823; and was chiefly educated at Dungannon College. I am informed that at a very early age he shewed much ingenious ability, which often took a humourous and mischievous turn, and that when 13 or 14 years old, he made a small working steam engine. The bent of the boy's talent induced a desire that he should enter the Royal Engineers, and for two years he was sent to the Rev. A. De La Mare, who prepared him for the Woolwich Academy.

The records at Woolwich show that in 1839, being 16 years old, he entered the Woolwich Academy; that in 1840 he passed his probationary examination; in 1841, his theoretical examination; in 1842, his practical examination, and came out sixth in a batch of 16 successful candidates.

Only 4 Engineer Commissions were given, and he was very nearly obtaining his commission in the Artillery, but his ability in drawing was so pre-eminent over that of his fellow Cadets, a fact worth recollection by all those who desire to be Engineers, that he was chosen out of his turn for the Engineers and obtained the third Commission.

He was only just of age when he fulfilled that destiny which seems so common to young Engineer officers, and took to himself a wife. He married Miss Rede, and soon after this event was sent out to Bermuda, where he seems to have excited attention by numerous clever devices for the rigging of a canvass

yacht, and tradition says that he spent most of his time on the water. The late Sir William Reid was the Governor at Bermuda, and it is remarkable that both these officers afterwards took such prominent positions in connexion with International Exhibitions.

On his return to England he designed and made the working drawings for the Raglan Barracks at Devonport, for which he obtained much credit. In this work he introduced, not without opposition, many useful novelties conducive to the health and comfort of soldiers, which are now accepted as necessities in Barrack accommodation.

In 1852 he invented a drawbridge, and in the year 1854, received his Captain's commission. About this time, before Whitworth and Armstrong had appeared as inventors in the manufacture of guns, he was scheming all kinds of ways of using elongated shot for rifled ordnance, but could never induce the military authorities to give his suggestions a trial. Little better luck seems to have attended his ingenious collapsing pontoons. What were the features of this invention, and what were its novelties, the Papers of the Corps of Royal Engineers, New Series, Vol. VII, p. 81, 1858, and the "Transactions of the United Service Institution" (see Journal, Vol. IV, 1860) shew. The military judges appointed to consider them were difficult to convince. No results at present have followed in this country from his labours, but I am informed that collapsing canvass pontoons were successfully used in the American Civil War. One of these pontoons was exhibited at the Paris Exhibition in 1855, and at a later period he made several improvements in them. He also perfected a light and portable one for Infantry, which could be transported by two men. The trial of these pontoons, on which his own corps has hitherto been unable to take decisive action, has been left in the hands of the First Middlesex Volunteer Engineers, who, at their own cost, have made many experiments.

When he was about to leave Devonport, in 1854, Captain, now Colonel Owen, R.E., then Secretary for the Paris Exhibition, accidentally met him in London, and justly appreciating his inventive ability, invited him to assist in superintending the Machinery Department of the Paris Exhibition, and Capt. Fowke was appointed to undertake the duty. Upon Colonel Owen leaving for the Crimea, he succeeded him as Secretary to the British Commission, and resided in Paris during the year of the Exhibition. He conducted numerous valuable experiments on the strength of colonial woods. The results were published in the Parliamentary reports on the Paris Exhibition of 1855, and subsequently reprinted as a pamphlet on "Civil Construction." At the same time he

drew up a report on the objects exhibited under the head of "Naval Construction." For his services to the Paris Exhibition he was made a Chevalier of the *Légion d'Honneur;* but as the decoration was given for civil and not for military services, he was unable to wear it in this country. In Vol. V, 1856, of the Corps Papers, is his project for Batteries, &c., for the defence of coasts.

He was appointed at the conclusion of the Paris work in 1857 to the staff of the Science and Art Department as an Inspector; and upon the transfer of the Department from Marlborough House to South Kensington, he was charged with the superintendence of the buildings there, which at that time consisted of the iron shed called "the Boilers," built by Sir William Cubitt, and a nest of old houses which had been inhabited, when Brompton was a suburb, by Mr. Greenwood of Messrs. Cox and Greenwood's, by Sir Cresswell Cresswell, and Madame Celeste. The Duke of York was accustomed to retire to Mr. Cox's House for change of air. It was Captain Fowke's duty to bring the iron shed, the old dry rotted houses, and a series of wooden schools into a working unity, which he did with skill and economy. In the midst of this work he was called upon to build a picture gallery to receive Mr. Sheepshank's gift of pictures, and he did so in concert with Mr. Redgrave, R.A., who had discovered the right formula for a top-light gallery. The building proved very successful, and, before it was finished, other galleries were required to receive the Vernon and Turner pictures, and he built these at a cost not reaching 4d. a cubic foot.

Constitutionally, nature had given Captain Fowke a sluggish and indolent temperament, but he was roused to prompt action occasionally. A signal example of this occurred with these picture galleries. If they were to be built at all, they were to be done in the shortest possible space of time. Capt. Fowke was on a visit to the Marquis of Salisbury, at Hatfield, when the Treasury decision was made. One evening Lord Salisbury told Captain Fowke that the work was to proceed, and briskly. The next morning, at breakfast, the Chancellor of the Exchequer, also on a visit at Hatfield, asked Captain Fowke when the works would begin. "They are begun already." "How so? you only knew last night at twelve." Captain Fowke replied, "I was at the telegraph office, at Hatfield, as soon as it was open; I ordered the works to begin, and I have received an answer that 'the foundations are being dug.'" "I call that work!" said Mr. Disraeli.

In 1858, he was named, at Sir John Burgoyne's advice, a Commissioner of the International Technical Commission, for rendering the St. George's branch of the Danube navigable, and his scheme was unanimously adopted; but, from various

causes, diplomatic and otherwise, his plan has only been partially carried into effect. His report to Lord Cowley was privately printed. About this time, he was called upon to design the interior of the Dublin National Gallery, the elevation having been already settled. It is a successful gallery both for day and night use. He also designed the Museum of Science and Art, at Edinburgh, which was opened lately by the Duke of Edinburgh.

It was at his suggestion that the first Corps of Volunteer Engineers (the 1st Middlesex) was formed. He planned the erection of their drill shed, covering 100 feet by 40 feet, which Sir Joseph Paxton commended to me as the cheapest structure he had ever seen. The cost of this was only £100 to the Corps, some of whom gave their labour, and the principle of its construction has been adopted at the entrance of the Royal Horticultural Society's Offices and the conservatory entrances, and frequently for drill-sheds throughout the country.

In the *Cornhill Magazine* (No. 6, June, 1860, Vol. I), he published a paper entitled "London the Stronghold of England," being a plan for the defence of London in case of invasion, which attracted much notice; and in the same periodical (No. 3, March, 1860, Vol. I) he offered suggestions for the enlargement of the National Gallery in Trafalgar Square, under the title of the "National Gallery Difficulty solved."

He prepared the general plan for the Horticultural Gardens, which Mr. Nesfield afterwards modified in the gardening details. The conservatory and south arcade were built wholly after Captain Fowke's design. Mr. S. Smirke, R.A., was the architect of the north and centre arcades. The conservatory is one of Captain Fowke's most successful works. He introduced here the principle of gas lighting which he had applied to the picture galleries, and the conservatory can be brilliantly lighted with perfect ventilation, and without damage to the plants.

At the request of the Prince Consort, he designed the Library at Aldershot, which His Royal Highness built at his own cost. The Prince sent him a box of instruments inscribed as follows, "Captain Francis Fowke, Royal Engineers, as a token of regard from ALBERT: 1859."

Captain Fowke, having laid out the ground at Kensington belonging to the Commissioners of 1851, was called upon to show how a building suitable for International Exhibitions might be erected on part of it. He therefore planned the series of buildings used for the Exhibition of 1862. His business was to

cover twenty-two acres of ground, having command of only very limited funds. The main feature of his plan was a noble hall, 600 feet long, 300 feet wide, and 200 feet high; but want of funds compelled the abandonment of this, and he hastily substituted instead the glass domes, which proved unsuccessful. But in respect of the picture galleries and the general exhibiting space the buildings were by far the most convenient that had ever been used for exhibitions. The exact proportions of the picture galleries and system of lighting have been adopted for the Paris Exhibition of 1867. There was no money to pay for the decoration of the outside of them, and public opinion refused to believe it could be decorated. Captain Fowke was very patient under much unjust treatment, but he apathetically refused to take any measure to rectify public opinion until it was too late. Two years afterwards justice was done to his talent. In an open competition of designs for buildings to be erected on the site of the 1862 Exhibition, his plans obtained the first premium, the judges being Lord Elcho, M.P., Mr. Tite, M.P., Mr. Fergusson (all of whom had taken an active part in pulling down the Exhibition buildings), Mr. Pennethorne, and Mr. D. Roberts, R.A., and they unanimously gave Captain Fowke the first prize. It was with difficulty he was spurred on in this case to compete, and he had not made up his mind to do so until within seven weeks of sending in the drawings.

Amongst several other of his inventions may be named a very portable military fire-engine, which has been adopted in the army; a collapsing camera; an improved umbrella for which he took out a patent—but the difficulties of manufacture prevented its adoption; (the principle of it was to bring the ribs within the stick or rod, so to reduce the circumference to the size of a small walking-stick); a portable bath to pack up like a book; also a lighting machine which is used throughout the Kensington Museum, and by means of which hundreds of gas burners are lighted in a few seconds.

At the desire of the Marquis of Salisbury, whilst he was Lord President of the Council in 1858-59, Captain Fowke devised plans for permanent buildings to be used at the South Kensington Museum; and in 1860 he was called upon, whilst Mr. Lewis's committee in the House of Commons on the South Kensington Museum was sitting, to put these plans into a more definite shape. He did so, and both plans and elevations may be found in the report of that committee, ordered to be printed August 1st, 1860.

He proceeded to build, in accordance with these plans, two large glazed courts. For the larger of the two, the interference of columns with the objects

exhibited, as in the court of the new Natural History Museum of Oxford, suggested the glazing over of the whole quadrangle, of about 100 feet span, without a single support.

It was not until the year 1861, that Captain Fowke commenced any decorative exterior for the Museum. With the aid of Mr. Godfrey Sykes, the official residences were then commenced, and the style was introduced with greater boldness in the lecture theatre adjoining.

This noble and certainly original work was in course of construction when Captain Fowke died, in December, 1865, and he did not live to see erected the highly decorated terra-cotta columns which Mr. Sykes had designed as their principal feature; nor did Mr. Sykes himself, for he too died, while the capitals were being placed on them. The plans and elevation which Captain Fowke left will be found in the reports of the Science and Art Department.

There was much affection between these two eminent men, and when Captain Fowke was arranging the Guards' ball in the Picture Galleries of the Exhibition of 1862, and Mr. Sykes was too feeble to mount the steps, Captain Fowke carried him up in his arms.

Captain Fowke, in the spring of 1865, had been working unusually hard at the drawing for the completion of the South Kensington Museum, and, feeling much fatigued, in the month of August he went to Switzerland, hoping to recover his health; but he came back much worse, with many alarming symptoms. These had been subdued, and he went to Eastbourne, where he remained till December. Two days after his return to his residence at the Museum on the 4th of December, 1865, whilst sitting in his chair a blood vessel broke. He exclaimed—"This is the end," and spoke no more. He was buried at the Brompton Cemetery, being followed to his grave by numerous brother officers, friends, and assistants. He was greatly beloved and is not known to have made a single enemy. The Science and Art Department have commissioned Mr. Woolner to make a bust of him to be placed in the South Kensington Museum.

Captain Donnelly, R.E., who had worked with him at Kensington for years, and made several good photographic liknesses of him, has justly remarked in the *Naval and Military Gazette* that Captain Fowke's "mind, though essentially practical, was wonderfully pliant and original, and combined with a quick imagination, which gave him a power of viewing, whether common things or intricate problems, from all points and in new lights, and by, so to say, analysing them, grasping their essential requisites."

I see no reason to modify the opinion of my friend and colleague which I expressed at a meeting of the Society of Arts, and with it I conclude these brief notes:—

"I firmly believe that the arts of construction in this country have sustained a great loss by Captain Fowke's death. At this period, when art is so transitional, and science is making so many discoveries, and men's minds are seething with inventions; when the use of new materials is being constantly manifested, and the new adaptation of old materials is constantly entered upon, England has lost a man who felt the spirit of his age, and was daring enough to venture beyond the beaten path of conventionalism. Captain Fowke, to my mind was solving the problem of the decorative use of iron, and, by appreciating the spirit both of the Gothic and Renaissance architects, was on the threshold of introducing a novel style of architecture, when, alas! death, at the early age of forty-two years, has cut short his promising career."

HENRY COLE.

South Kensington Museum,
June 21, 1866.

PROFESSIONAL PAPERS.

PAPER I.

NOTES ON THE EMPLOYMENT OF SUBMARINE MINES, (Commonly called Torpedoes), IN AMERICA DURING THE LATE CIVIL WAR.

By CAPT. E. HARDING STEWARD, R.E.

The subject that I have selected for a paper, is one that has lately occupied the attention of many of our own Service, and has excited generally a considerable interest on account of its great importance as well as its novelty. The circumstances that led me to take up the subject are as follows:

During this summer*, when on duty at Bermuda and Halifax, I fell in with several American officers who had been serving in the late Civil War. Torpedoes and their employment having been always a subject of interest to me, I naturally endeavoured to get all possible information about them and their employment in actual war. At first I obtained only vague and conflicting statements and no details. But my informants eventually procured for me an introduction to the officer, who, during the latter part of the war, had conducted the submarine mining operations in the South. That gentleman, Captain Pembroke Jones, was, when I made his acquaintance, serving as Second Officer on board Captain Maffit's blockader "Owl;" and the vessel had, fortunately for me, put into Halifax for repairs during my short visit there. My acquaintance with Captain Jones led to others in England, particularly to that of Captain Hunter Davidson, who was his predecessor, and had superintended most of the submarine mining arrangements during the greater part of the war. From other officers I also got information confirmatory of some of the accounts of the employment of torpedoes and their bearings on the war; also of some of the Federal doings in that line.

In treating the subject I propose first to sketch roughly the history of torpedoes down to the commencement of the late Civil War; then to give an account of the submarine mines as employed by the Confederates, together with what I

* 1865—This paper was written for the autumnal series of evening discussions at the Royal Engineer Establishment, at Chatham. Portions of it were there read on the evenings of November 3rd and November 4th (1865).

have been able to collect about the Federal operations; and to conclude with a short account of the employment of torpedoes on land by the Confederates.

It is impossible to say when and by what nation torpedoes were first used. The first recorded experiment occurred in October, 1805, when one Robert Fenton blew up a 200-ton brig off Walmer Castle by torpedoes. The experiment was made in the presence of Sir Sidney Smith, Admiral Holloway, and other officers. A submarine boat was used in attaching the torpedoes to the side of the vessel, and ignition, by means of a flint lock and priming powder, was effected with clockwork set to liberate the hammer in a given time. Fenton carried on experiments also at New York and other parts of the United States, and it is said that he was employed by the French during the great war to blow up a British man-of-war in the Channel; but the attempt failed, owing to the vessel moving off at the critical moment. Fenton afterwards wrote a book on torpedoes, but as no assistance was held out to him by the British or any Foreign Governments, the matter dropped. It however excited considerable interest at the time.

In the Baltic, during the Russian War, floating torpedoes were made use of, but the charges used were small. They were arranged for ignition by means of acid fuzes. No damage was caused by them beyond the ripping off of some of the copper and the breaking of some of the ward-room crockery. The machines themselves were easily discovered and fished up by the boats of our Fleet.

The Chinese also employed some kind of infernal machine against us in the recent war, but without results.

Most European nations have, during the last twelve years, paid attention from time to time to submarine mining, and investigations have been carried out by order of the different governments. The various experiments conducted on their account led to immense improvements in the modes of igniting charges. But as regards the establishment of a system, nothing in Europe has been done except by the Austrians. Under Baron Von Ebner, their Engineers have developed a complete system of submarine mining, and have also applied gun-cotton to that purpose.

Soon after the commencement of the war between the two sections of the American Union, the advantages to be gained by the use of submarine mines were perceived in the South, and the Government at Richmond decided to adopt them as useful adjuncts in the defensive war then going on along the sea-board, and as obstacles to raids made by the Federal gunboats up the rivers of the Confederacy. Captain Maury and others then turned their attention to torpedoes, and a great impetus was given to the scheming out of various kinds. The torpedoes first employed were rude and ill-constructed, and proved only partially successful. They were, however, the foundation for what followed.

Drifting Torpedoes.

In the early part of the war drifting torpedoes were used. Of the drifters there were various kinds. In some instances a pair of barrels of powder were floated down a river towards the bows of a vessel. The barrels were provided with a lock and fuze, and were weighted and slung to buoys so as to float 12 feet below the surface. The buoys were placed 200 feet apart and connected by a rope supported by a third buoy in the centre. To cause the explosion, a cord was passed from the head of the sling to the trigger, and arranged in such a way that when the barrels, after a check,

became forced on their side by the current, the hammers would be released. In floating them down a river against a vessel, the direction was given to the centre buoy in such a way as to cause it to catch in the bows, and then the current would make the barrels close under the quarters. This kind of drifter did not realize any success, for the buoys generally fouled something before they reached the vessel, and in the single case in which they did reach their destination, viz., when drifted against the Minnesota by Captain Sinclair of the Confederate States' Navy, the fuzes became extinguished, owing to the composition being unsuited to the depth of water.

On other occasions, barrels of powder were weighted, and had fitted on their tops a small four-bladed screw acting on a bolt that retained a hammer. These were drifted down towards vessels, and it was supposed that when they came in contact with a vessel and ceased to move with the current, the screw would commence to work. Its revolutions would by degrees draw the bolt and so liberate the hammer, letting it fall on a percussion cap fixed for the ignition of the charge. This kind of drifter, one must own, is highly ingenious, but no good result came of it. Small cylinders filled with powder and packed inside barrels with hay, were also drifted towards vessels. These were fitted with detonators, but, like the rest, they failed to close on the enemy.

The want of success that attended the use of drifting torpedoes, determined the Officer in charge of the submarine mining arrangements on the James River never to employ them again. In confirmation of the soundness of this judgment, I must mention a circumstance that happened later in the war. When the Confederate forces lay round Richmond, in the summer of 1864, the Engineers of the army conceived the project of destroying Admiral Lee's fleet on the James River, by floating down a great number of drifting torpedoes. The torpedoes employed on this occasion had metal cases, and were provided with several very sensitive detonators. In all, eighty torpedoes were floated down, and it appears from the account given by the Federals that they were all caught in advance of the ships and fished up with the greatest ease by the boats of the fleet. It will thus be perceived that drifting torpedoes, as employed by the Confederates, were of no use. In fact it is evident that with the most perfect machines, and under the most favourable circumstances, there could only be a small proportion of success, for, besides their own uncertainty, the simplest precautions on the part of the enemy, such as nets or outriggers, are sufficient to keep them off or explode them harmlessly in advance.

The Confederates having found that drifting torpedoes gave bad results and produced but slight moral effects, owing partly to their inherent defects, and partly to their opponents being too wide awake, they set to work to devise a mine that would be out of sight. This brings me to *stationary torpedoes* under the surface of the water. These torpedoes or submarine mines, as used by the Confederates, were of various forms and differently employed. They can be divided into three distinct classes :—

1. Torpedoes fixed at the end of spars anchored in a stream or on piles driven into the bed. These were called *stake guns*.

2. Torpedoes moored to the bottom and floating below the surface, arranged to be fired by contact or by electricity.

3. Torpedoes at the bottom, arranged to be fired by electricity.

Stake Guns.

Stake guns were used by the Confederates principally on the Mississipi River. They are suitable to shallow tideless waters. They cannot be used in greater depths than four fathoms, and only where the current sets always one way. To fix them, long beams of timber were moored by one end to a heavy stone or mushroom anchor (vide Fig. 7, Pl. II), a very short connection being used; at the other end was fixed the torpedo. The angle at which the beam floated was found by experiment, and the length was arranged so as to bring the end of the torpedo about 3 feet below the surface or sufficient to avoid ripples; the proper level of the end being ascertained by means of observation of the rise of the river. The beam was further secured by a mooring and rope in front. This was added to steady the beam and to keep it from swinging.

The torpedo employed was a case of sheet iron, long and rounded at the head, and made to fit over the end of the beam (vide Fig. 9, Pl. II). The charge was usually 25 lbs. of powder, and ignition was effected by means of detonators (vide Fig. 6, Pl. II). Four were generally provided, and arranged in such a way, as to insure contact. Similar torpedoes were also fixed in some instances to stakes or piles driven into the bed of the river. This application of torpedoes is very effective under particular circumstances, and two Federal gunboats were destroyed by them.

Detonating Torpedoes.

Submerged detonating torpedoes were very generally used by the Confederates. In the earliest part of the war they employed stout glass five-gallon bottles, called demi-johns, as cases for the charges. These had 25 lbs. of powder in them and were fitted sometimes with a detonator, but more frequently with a trigger and an Ely cap. The demi-johns were placed in baskets or frames and moored a little below the surface. These extemporised torpedoes were employed with success on the Cumberland and Tennessee Rivers, and three Federal gunboats were destroyed by them. Cylinders made of thin boiler-plate iron placed inside barrels and stuffed round with hay or straw were next used. The necessity of employing strong metal cases was soon discovered by the Confederates, for besides doing away with leaking and consequent deterioration of the charge, greater effect was produced by confining the powder during the first moments of ignition. Specially made receptacles were not, however, always at hand, in which case the barrel containing the powder was strengthened with iron hoops, and paid over with tar, and put inside another barrel, and, as a precaution, the torpedo was given a double charge to make up for want of resistance. All these were rude beginnings, but the submerged detonating torpedo was rapidly improved, and a pattern known as Singer's patent was ultimately used by the Confederates (vide Fig. 2, Pl. II). The case of this torpedo was made of ¼-in. boiler-plate iron, and had the form of a reversed cone with a top nearly hemispherical. These torpedoes were made to contain from 75 to 100 lbs. of powder, and, prior to use, were carefully tested with hydraulic pressure. The filling hole for the powder was at the point, and plugged with a thick brass screw that had a large eye at the end. To this the mooring rope or chain was attached. The air chamber, to give the torpedo buoyancy, was at the top. For the ignition of the charge four very sensitive caps were put inside the torpedo, on nipples, (vide Fig. 1, Pl. II), and brought with their heads in contact with sides of the case. At these points

the metal was beaten thin in order that the blow of the hammers arranged on the outside of the case, to strike over the caps, might not be deadened. The torpedo case was also provided with four arms or feelers, with claws at the ends and fans in the middle, so that they could not fail to be moved by anything coming in contact with them. These arms, when touched, liberated the hammers, and by some arrangement that I never could ascertain, the motion of one was communicated to all four hammers, so that the four caps were exploded at once. These detonating torpedoes were moored 4 feet below the surface in order to avoid ripples which would certainly indicate their position to an enemy. For moorings, the Confederates employed large blocks of stone or mushroom anchors, and connected them with the torpedoes by a rope or a single chain with a swivel at the end. This kind of torpedo was subject to such considerable disarrangement by the currents and floating timber that it never could be maintained in order for any length of time. The current, when strong, imparted to it a rotatory motion, which twisted the ropes or chains so much that the torpedo was drawn down towards the bottom. It has, besides, the disadvantage of being easily taken up by an enemy with scoops or rakes, unless so heavily weighted that it could not possibly be lifted from a boat, and this the Confederates did not generally do. These self-exploding detonating torpedoes are also unsuited to any channel or river which has to be kept open for navigation; but when the navigation need not be maintained for purposes of supply or communication, they may be mutiplied to any extent, for the enemy alone gets the benefit of them.

Notwithstanding all these objections, the submerged detonating torpedoes were used extensively by the Confederates, and with great success throughout the war, even after the invention of mines on the bottom fired by electricity. The reasons were these. The shores of some of the rivers in the South were so swampy and pestilential that the arrangements necessary for any mines but detonating ones were impossible. The mosquitoes and snakes alone would probably have driven off the torpedo detachment sent for observation and to fire the mines. Mining operations had also frequently to be carried on in rivers passing through country that could not be occupied by the Confederate forces, and the shore preparations for electrically fired mines can only be made and maintained in parts from which the enemy is excluded.

On the Roanoke River, in December 1864, submerged detonating torpedoes were employed with great success. They had been laid in the river with the object of preventing the Federal gunboats from passing up ~~the~~ to Welden and destroying the railroad bridges. One hundred of Singer's detonating torpedoes were laid in this instance. The Federal squadron of nine gunboats advanced up the river, and although they were prepared with sweeps and rakes, the torpedoes were too many for them. Out of nine gunboats three were sunk, and four were so seriously damaged that they could not be employed again. Several lives were lost on this occasion from the current sweeping the men down. The Roanoke River was a difficult place to mine in, for, owing to the mountain torrents and the rain, it was subject to sudden rises, and had an exceedingly strong current. After the affair was over, many of the torpedoes were found drawn down and their moorings twisted. It is supposed that out of the hundred torpedoes not more than thirty kept their proper levels and places.

On the St. John's River, in Florida, detonating torpedoes were eminently successful. Captain Bryan, of the Confederate States' Service, was detached from head-quarters on the James River, in the spring of 1864, to cut off the communication between the Federal forces at the mouth of the St. John's River and the troops posted in the interior. He took with him a small party and some of Singer's detonating torpedoes. The river is very broad, but shallow in places. With a view to selecting a spot for his machines, he concealed himself in the marshes on the shore, and observed the course of the Federal transports at a certain bend of the river. On a particular spot he lined pairs of poles from two points, so as to give cross bearings to the spot in the channel. Under cover of night he put off in a boat, and having caused lanterns to be fixed on the poles, he succeeded in placing himself exactly on the spot he had observed. There he dropped one torpedo, and the rest he put round it in a circle, in order to cover a considerable space and insure the striking of one at least. A few days after this operation three large Federal transports were destroyed by these torpedoes, and this led to the temporary withdrawal of the Federal force from the interior.

On the James River no success attended the employment of detonating torpedoes; but a Confederate flag-of-truce boat was blown up, owing to one of a line of mines having dragged its mooring and drifted beyond the spot indicated on the surface by the private marks.

Detonators.

Torpedoes of the same form were arranged to be fired by detonators of a very superior kind known as Brook's fuze. Five of these detonators were fixed round the sides, but though highly sensitive and admirably adapted for the purpose, contact with a vessel did not always produce an explosion, and the uncertainty could only be remedied by putting the detonators all round. Brook's fuze is excellent when a direction can be given it. The detonator is made of brass, in the form of an ordinary nipple, only more rounded at the head in order to secure an explosion from a lateral blow (vide Fig. 6, Pl. II). The nipple screws into a socket inside, and is rivetted to the case of the torpedo with a washer of vulcanized india-rubber between the flange and the socket. When prepared, the vent of the nipple is primed with fine rifle powder, and a detonating compound is placed on the head of the nipple. The head used to be protected by a piece of thin lead which was brought down and screwed to the top or square-headed flange, but that was subsequently changed for copper as it proved too compressible. The composition of the detonating compound was made of nine ingredients, and was mixed so as to go off at any pressure determined on. The pressure generally allowed for was 4 lbs. for submarine mines and 8 lbs. for military mines. I was not able to find out the nature of the composition, but one that would meet all requirements could easily be made. I know that fulminate of mercury had been tried, but was abandoned on account of the difficulty of controlling it.*

* Since this paper was written is has been found that the sensitive substance at the head of the Brook fuze was fulminate of silver, and that the copper covering was varied in thickness according to the force with which the substance was required to explode. The detonating compound invented by General Raines was used only in the fuzes for the torpedoes employed by the army.

Submerged Floating Mines.

The James River being the head-quarters of the submarine mining staff, and its banks being generally occupied *in force*, torpedoes could be arranged to be fired by electricity. These torpedoes, being several feet below the surface, may be called *Submerged Floating Mines*. Iron cylinders inside barrels were first employed. They were dropped into position from a small steam tug, and the line of the torpedoes taken up on shore at the same time for the establishment of the range station. The insulated wires were led under the line and up the different moorings. Two wires were always used, one of which, in each case, was led along the bottom from the torpedo to the side of the river, and the other connected with the next torpedo. This was done in order to secure the simultaneous explosion of any particular pair if necessary. The insulated wires in all cases were covered with canvass and wound round the moorings and bound to them with copper wire at intervals of 6 feet. The laying of this kind of torpedo, when arranged to be fired with electricity, was a difficult and anxious operation; they were moreover subject to the same disarrangements as the detonating torpedoes; and in the James River the current and floating timber were fatal to them, for some became entangled and had their wires severed, while others were tied in perfect knots by the rotatory motion imparted by the stream. The addition of swivels was found to mitigate the evil only in a slight measure. The difficulty of mooring the submerged floating torpedoes and maintaining them free from disturbance by the enemy or the tide, also the inconvenience they were to the navigation, all led the Officer in charge of the submarine mining operations to reject them in the case of the James River, in favour of large charges placed at the bottom.

The employment of large charges placed on the bottom was first suggested by Captain Maury. The charges were placed by him in cylindrical boiler-plate tanks or in small boilers, and lowered to the bed of the James River, the wires from each being led to the side. These particular mines were not, however, used, as the wires were parted by the tanks shifting about during a freshet, and the tanks themselves were ultimately lost. This shews the necessity of weighting the tanks that contain the charges or securing them to heavy mushroom anchors. Loose powder having the same specific gravity as water, one can understand why any additional commotion in the river should have caused the tanks to shift about. The battery employed by Captain Maury was on Wolloston's principle, but made on a gigantic scale, with the view of obtaining *quantity* of electricity. This battery proved cumbrous in the extreme, difficult of transport, and required a vast amount of solution. It also weighed, when filled, nearly one ton. All this, and the laying of the submarine mines, was subsequently improved. Captain Maury, shortly after the loss of the tanks, left for Europe, to be employed as an agent for the Confederate Government, and as soon as his business was completed, he set to work to collect the best information on the firing of charges under water. He also purchased and forwarded to the Confederacy the most approved stores and appliances.

In May, 1862, the Confederate submarine mining operations came under the control of Captain Hunter Davidson, through whose energy and ability, and with the help of the new supplies of stores, they assumed larger proportions; they also began to be subject to a regular system. A Torpedo Detachment had then been recently raised; also a Mining Bureau, formed at Richmond, with

Brigadier General Raines at its head. It is this officer who invented the composition for the detonators. He pressed the use of torpedoes on the American Government as far back as the Mexican War, and advocates their employment on all occasions in time of war. In fact detonating torpedoes is with him a monomania. General Raines' staff consisted of one captain and two lieutenants. They were employed exclusively with the army, and the assistance they required was obtained from the nearest regiment.

Torpedo Corps.

Submarine mining was special work, and was made a distinct service. The officers were taken from the Infantry, as applied for by Captain Davidson. They were selected for special qualities, taken for a time, and employed independent of their rank. The men were all picked men, taken generally from the class of small farmers. There were likewise some old warrant officers from the Navy, who were also mechanics. It was found very necessary to have a superior class of men for the carrying on of the duties, which necessitated the possession of a certain amount of education and discretion, with a considerable degree of nerve and courage. The men had also to be above all suspicion of sending information to an enemy, for secrecy is the key to success in submarine mining. The real organisation did not extend beyond Virginia, but service was performed from time to time by officers detached temporarily from the head-quarters of the mining branch on the James River. The Torpedo Bureau at Richmond supplied and arranged the torpedoes used by the army, and sometimes issued stores to the officers of the submarine mining branch employed in different parts of the Confederacy, but in no way controlled the officer in charge. On the James River the submarine mining establishment consisted of two large tugs, a store vessel, six torpedo boats; also four waggons and six ambulances for moving the mining staff and batteries quickly from point to point. When required, more waggons were obtained from the Quarter-Master General of the Army.

James River Mining Arrangements.

The James River is the line along which the Federals tried repeatedly to penetrate to Richmond. To prevent the Federal fleet from co-operating with the army, was therefore of vital importance to the Confederates. After the sinking of the Merrimac, and the loss of the other ironclad ships, the Confederates depended entirely on the mines in the river to check the enemy's ships. There was a battery near Hawlett's house (vide Pl. I), and one at Chafin's bluff; and higher up, at Drury's bluff, there was a large work with guns commanding the river, and in front an impenetrable obstruction of sunken ships and lines of cribs filled with stones. Other batteries would have been made lower down the river had it not been for the necessity of dismantling and abandoning them on the advance of the Federal army. Consequently mines were employed, and they proved under the circumstances more useful than batteries, as they could be quickly established or withdrawn. The positions of the mines depended on the line occupied by the Confederate forces, and they generally advanced or retired with the line of the Confederate pickets. The chief object of the mines was to prevent the Federal fleet from acting on the flank of the Confederate army, when it rested on the river, and from making raids. Whenever the banks of the river were in the hands of the Federal troops, owing to some advance, the mines were taken up in a night and

retired near to the line of the Confederate pickets for support. To effect these changes of position properly, perfect arrangements and great dispatch were necessary. In the absence of the Confederate army, the James River mines were, however, sometimes laid many miles in advance of their supports. To escape detection by the Federal fleet, dependence in such cases was placed on the shore arrangements being well concealed or of such a nature as not to rouse suspicions. On the river there were during the last two years of the war nine Torpedo Stations (vide A, Pl. I). The battery houses at these stations were connected with wires, and the telegraph line continued to Signal Hill, with a branch to Chafin's bluff, and then on to the Signal Bureau at Richmond. Thus the submarine mining arrangements afforded along an important line a good link in the system of rapid communication of intelligence so necessary when in the presence of an active enemy.

Submerged Torpedoes at bottom.

In my description of the mines employed by the Confederates, I left off at the point where they had commenced to use torpedoes at the bed of the river. Where the Confederate forces were established, this kind of mine was generally employed from that time in preference to all other kinds, for it was reckoned to be more certain and much more demoralizing, less likely to be disturbed by the enemy, and more under control, as its state could be determined at any time. Besides all this, it was not a source of danger to friends, as the floating and drifting torpedoes were.

The tanks to contain the charges for the ground or submerged torpedoes were made of $\frac{1}{2}$-in. boiler-plate iron (vide Fig. 3, Pl. II) in the form of a cylinder with conical ends. They had to be made with great care, and were tested by hydraulic pressure up to 180 lbs. on the square inch. On the top were strong eyes attached by straps rivetted to the tank. These were used for lowering the tank into position, and to them were also attached the chains that connected the tank with the mushroom anchors employed for weighting down the mine (vide Fig. 17, Pl. III). At one end of the tank was a large brass plug made with an eye (vide Fig. 5, Pl. II). This closed the filling hole. At the other end there was another brass plug made like an enormous shell fuze (vide Fig. 4, Pl. II). This plug is lined with stuffing to take the wires, and screwed into a thick brass disc which forms the end of the tank.

The charges for these mines varied from 1,000 to 5,000 lbs. of powder, according to the depth of the water, the hardness of the bottom, and the structure of the vessels they were intended for. These charges are very much in excess of what is requisite for making a hole in the bottom of a vessel, even in a considerable depth of water. The object the Confederate officers had in using such a quantity of powder was to control a large area of the surface of the water and to insure the destruction of a vessel, even when at a little distance from the mine, through the commotion of the water alone; for they foresaw that imperfect estimates might be made as to the relative position of a vessel with a particular mine.

The insulated wires, after being passed through the plug, were fastened to a stick, cut so as to reach the centre of the tank. At the end was the fuze. When a galvanic battery was employed, as was generally the case, it consisted of a connection of very fine platinum wire covered by a quill filled with fulminate of mercury; this, with the ends of the wires, was inserted in a small bag of

fine grained powder, and protected by an oilskin cover. The plug and stick were carefully screwed into the end of the tank, and the wires, which were covered with canvass, were taken over the head of the tank and secured by copper wire to the eyes; they were then passed on to the large eye at the end, from which they were led to the shore.

Wires. The wires employed were generally single copper wires of No. 16 gauge, but sometimes three finer wires of No. 24 gauge were used instead. These were covered with two coats of vulcanized india-rubber. This material was of a superior kind and free from all foreign substances. It was found to last well and not to deteriorate when under the influence of damp or heat. The same insulated wire was sometimes used for the water portions of the circuit; but in the case of large mines at the bottom a stouter cable was laid. This was a similarly insulated wire with a covering of tarred hemp, and bound round with ten strands of iron wire for protection, making the total thickness of the cable about half an inch.

Situation. On the general position for a set of mines on the James River being determined, with reference to the line to be defended and the probable position of the supports, a careful reconnoissance had to be made by the Officer in charge of the mining arrangements, to enable him to decide on the exact spots where to lower the tanks containing the charges. The part of the river under a bluff, and a little in advance of a ravine or gully, if such existed, was generally selected. The height of the bluff prevented the range station from being observed from vessels in the river, and moreover gave good inclined lines of sight or directions to the surface immediately above the mines. The ravine or gully would also afford a concealed position for the battery station and the hut for the torpedo staff, besides offering a convenient place for landing the shore-ends of the cables. The number of mines would depend on the width of the navigable channel and the distance apart. The latter of course being regulated by the area of the water surface lifted by the explosion. On the James River the charges generally employed varied from 1,700 to 2,000 lbs. The mines were placed 50 yds. apart, and the depth of water in which they were exploded was on an average seven fathoms. The bottom in all cases was of soft mud. This alone, as proved by experiment, diminished the effect of the charge by one-fourth, as compared with the result on a rocky bottom. For the placing of the tanks a steamer was used. The mooring chains were about 12 feet long, and attached to heavy mushroom anchors or long bars of iron. In the latter case the fastening was made towards one end, in order to cause the bars to hitch against the bottom. The tanks and weights were carefully lowered from the steamer by chains coupled to the shackles of the mushroom anchors, and fine lines of cord were led from the tanks to the surface, to which were attached twigs or small boughs of trees to indicate the points of immersion. These were chosen as private marks in preference to the smallest floats or buoys, as an enemy in searching the river would mistake them for drifting wood or snags*. The tanks were lowered in a row, and the prolongation taken up on shore at the same time for the accurate determination of the site for the range station.

* Snags are the ends of trees, floating down a river or caught in the bed, which shew above the surface.

Range Station.

The range station is the concealed place from which vessels are marked down and the circuit is closed. The Confederates always endeavoured to line the mines so as to bring the range station under a tree, or at least on the reverse slope of a hill, in order that the disturbance of the ground for the formation of the pit should not be observed by an enemy advancing. It is very important that suspicion on the part of an enemy should never be raised by the sight of preparations, for, if observed, and the mines do not happen to be covered by the fire of supporting works, a party could be immediately landed to destroy the range and battery stations and to cut the wires. The range stations made for the mines on the James River were small pits into which the wires were led. To give the lines to the points on the surface of the water over the mines, a pair of reeds were planted in the direction of each, and when the range station was high, the reeds were made to shew the exact spot by being run home until their tops gave the angle of depression from the point of observation. This last precaution was not always necessary, for constant observation of the points over the mines made the look-out-man or observer so familiar with the distances that his judgment could be freely trusted up to 600 yds. Now and then, when mines were employed at greater distances, cross bearings were used, but no occasions arose for the employment of an elaborate range system. The closing of the circuit was effected by crossing the wires. For firing mines, whether with a battery or a machine, the simplest method of closing the circuit should be selected. Any double motion in this operation should be avoided, as all possible attention is required for the observation of the vessel when close to the mine. This requires in any case quick sight and judgment, and considering the interests at stake, it is evident that without great calmness and superior nerve a well-timed explosion cannot be reckoned on.

Battery Station.

The battery station is a pit similar to that at the range station, but with a splinter-proof cover. The Confederates generally placed it about 200 yds. away from the range station, but its exact position depended on the ground. A hut for the men of the Torpedo Staff was always established near at hand, for on the James River a strict look-out had always to be maintained from the range station, and the sligherst movement of the enemy, when in the reaches below, telegraphed to head-quarters. An interval between the battery station and range station is most necessary, for talking and confusion at the time of the closing of the circuit would infallibly cause a mine to be exploded prematurely.

Arrangement of Wires.

Double wires were nearly always employed, and these were led from each tank in such a way that no risk of disturbance should occur to one set when the next tank was exploded. The wires, as they lay at the bottom, were not weighted. This precaution was not taken, and no inconvenience arose from it, for the enemy never had an opportunity of grappling over the mines laid at the bed of the river. Weighting is, however, very necessary. The wires were led to the shore, and when only a pair of mines was employed, two of the wires, viz., one from each tank, were then connected, and the single wire from the point of union led underground to the range station. It there was made to protrude about 18 inches from the ground, with a ticket marked *C* attached, it being the centre wire; of the other wires, one was led to the battery and the other to the range station, along deep trenches. A connecting wire between the range station and the

battery completed the chain. In this way the charges could be exploded singly or together. Every precaution was taken in laying the land wires, in order to give the enemy as much trouble in taking them up as possible, and to allow time for a diversion. The trenches were generally made 8 feet deep, and the ground was disturbed in various places for the purpose of misleading the enemy.

Batteries or Machines employed.

The battery generally employed by the Confederates was a 12-cell battery on Grove's principle. It was light, and made so that it could be packed and removed when filled. This was a great improvement on Captain Maury's first battery. The improved battery had platinum wire gauze instead of a thin sheet of platinum, and pure acids were used in order to produce an unusual *quantity* of electricity. Frictional machines were also now and then used for submarine mines in the Confederacy during the War, but with no great success, and towards the close of the war two or three of Wheatstone's magnet exploders were obtained. With one of them the mine at Mobile, that destroyed the Tecumseh, was fired. Two Ebonite exploders made on the Austrian plan were also forwarded to the Confederacy by Captain Maury, almost at the end of the war, but I never heard of their being used. The employment of these instruments for submarine mines was considered by the Confederates to be uncertain on account of the delicacy of the fuzes, and their preference was for the voltaic battery. This no doubt was owing to their not having become accustomed to the use of the fuze.

Testing.

Testing for continuity was regularly performed every morning and reported to the superintending officer. The officer also occasionally made tests for his own satisfaction, or when anything went wrong. The daily test was generally done by putting the wires to the tongue. This was regularly practised in order to be independent of the galvanometer. For submarine mining, testing is a *sine quâ non*. To illustrate its importance I will venture on a short digression.

At Charleston the Confederates had a single large mine at the bottom. It was 5,000 lbs. of powder put into an old ship's boiler. This they lowered in 6 fathoms of water at a point about 1,500 yds. from Fort Sumpter, to which place the wires were led, and where the mine was arranged to be fired by a large frictional battery. On the 8th of September, 1863, when the Federal fleet stood in closer to the batteries for the attack, the flag ship the "New Ironsides" approached the bar and came to a standstill exactly over the mine. Every effort was made to spring the mine, but without success, and the "Ironsides," after resting over it an hour and-a-half, slowly moved away, the officers and crew quite unconscious of the kind intentions of the enemy towards them. A frictional machine is no doubt better adapted for submarine mining than the voltaic battery, but unfortunately when all this occurred the testing arrangements were imperfect. The immense charge had been down at the bottom of the channel four months prior to this occurrence, and either the insulation or state of the charge had never been ascertained during all that time; or, what is equally possible, the testing had been performed, but, in doing it, the current had decomposed or deteriorated the composition at the top of the fuze and rendered it unfit for ignition. I am inclined to the latter view, because I have heard that the man in charge of the machine was put in irons for neglect of duty, notwithstanding his assertion that he had tested for continuity on the day previous to trial.

Powder.

The powder generally employed by the Confederates for the submarine mines was the finest grained powder that could be obtained, as the action must be quick. When the upheaval of the water is slow, the desired effect on a ship can never be entirely produced from the bottom. On experiments being made in a well in Pensylvania to ascertain the relative effect of different kinds of powder, 50 lbs. of rifle powder sent up a column of water 250 feet high, while with the same charge of coarse powder a column of similar thickness was only driven 70 feet high, and the water was very much discoloured, proving the non-ignition of part of the charge. With mines fired at contact, the quality of the powder is not of quite so much importance. It is necessary in such cases to confine the charges in a strong case and to arrange them well below the surface, as the superposed bed of water increases the effect of the charge. The mines will also operate in this way in the case of an iron-clad, below the belt of armour plating.

Gun-cotton.

Towards the close of the war a great quantity of Prussian gun-cotton was introduced into the Confederacy. In using gun-cotton one-fourth the weight of the charge in powder was considered to be the safest proportion by the Confederate officers. Although gun-cotton was never employed by the Confederates against the enemy in submarine mines, a series of experiments were made with it.

Charges.

With submerged torpedoes, as employed by the Confederates, the regulation of the charge depended on the depth of the water, the nature of the bottom, and structure of the ships expected; except in the case of small torpedoes moored a little below the surface and arranged for contact. With these the proximity of the charge to the object altered the conditions. The following scale of charges, suitable to depths from two fathoms and upwards, was made out for use in the James River, where the bottom is very soft. It is based on data obtained from the destruction of wooden vessels of 800 tons by the Confederates, also from experiments, and is suitable to strongly built wooden vessels up to 1,000 tons :—

2	fathoms	.. ..	300	lbs. of powder.
3	"	.. ..	600	" "
4	"	.. ..	900	" "
5	"	.. ..	1,200	" "
6	"	.. ..	1,500	" "
7	"	.. ..	1,800	" "
8	"	.. ..	2,400	" "

With hard bottoms the charges could have been diminished, for the waste of powder is then not so great. In the case of a rocky bottom, as much as 25 per cent. may be deducted according to the American experiments, because the rebound of the portion of the gas that acts downwards is almost coincident with the upstroke of the rest. These charges, even considering the objects in view, appear excessive, but it must be remembered that the Confederates used only one fuze for ignition. With proper arrangement for igniting the charges at several points a reduction might have been made amounting to 40 per cent. As I have before mentioned, the employment of large charges was made with a view of controlling a large area and destroying a vessel through the commotion

of the water when beyond the direct action of the charge. This plan may be a good one with small vessels, but the worst features of the system is the fact that, as in some cases, the result depends on the lifting powers of the charge, the quantity of powder must necessarily be increased in proportion to the size of the vessels expected. A progressive increase of one-third of the amount given in the foregoing scale, for every extra thousand tons of measurement, was considered by the Officer superintending the mining operations in the South, as the least that might be done in the case of large vessels. This no doubt is true, but with vessels of 3,000 to 4,000 tons it brings the charges to quantities too large for proper management.

Small charges fired near the surface.

In the case of the torpedoes moored below the surface, and intended to go off in contact with, or close to, a vessel, no variations for depth of water or nature of bottom were considered necessary, as these do not influence the effect of the explosion. On first consideration, the loss of power by downward action, in the case of a charge suspended in water, might appear considerable, but the resistance offered by the water below the charge is such that no greater loss of power is probably sustained than would be the case with a charge fired when resting on a soft bottom. By experiments made at Richmond against piling bolted and braced together, planked on both sides, and filled in to represent the hull of a well-built vessel of war, it was ascertained that, with absolute contact, a complete perforation and the starting of the surrounding timbers could be secured by exploding 45 lbs. of fine grained powder 8 feet below the surface. On repeating the experiment at lesser depths below the surface, the damage was diminished in proportion, and at 4 feet below the surface the effect of the charge on the piles was very slight. When small charges are used near the surface, perforation in any case is only possible when the torpedo is in absolute contact with the vessel and there is a certain weight of water above the charge. A small cushion of water interposed between the torpedo and the side gives the balance of resistance to the vessel. When such an occurrence is possible the charge should be increased in order to compensate for loss of power; for in the case of a small charge so placed, the action of the explosion on the vessel would be almost nullified. The superposed bed of water is also obviously necessary. It provides the requisite resistance over the charge that bends the explosion into a lateral direction; in fact it acts as tamping. This resistance must be in excess of that of the side of the vessel in order to produce a perforation, but when this is not the case, considerable damage may be done by using more powder, though the greater part of the explosion will of course be upwards.

Action of large charges placed at the bottom.

I have given, as nearly as possible, the views of the Director of Mines in the South on the subject of small charges fired near the surface, and I now come to the action of large charges on the bottom or bed. The opinions formed on the subject were the result of several experiments and of cases that actually occurred during the war. I must, however, remark, that except as regards the action on the bed, there were no means of estimating the movement of gas under the water, or the exact dimensions of the columns of water upheaved. The conclusions thus arrived at are the result of certain impressions, and may be proved to be not entirely correct; but, in any case, a theory on such a subject can only be accepted on the testimony

of several independent observers. In exploding a charge resting on the bottom, the gas first acts in all directions, but its ultimate course depends on the resistance met with, for the explosion naturally follows the line of least resistance. The downward action of part of the gas was evidenced in the case of some explosions on the James River, by the large holes that were found under the point where the charges had been fired. In these instances the bottom was of soft mud. With regard to the rest of the gas, when in deep water, the resistance offered by the body of water at the sides was supposed to bend the explosion into a direction more vertical than was the case with similar charges fired in shallow water. This fact was only indicated by a more extended disturbance of the surface, and not by any difference in the shape of the column thrown up, which, in all cases, is vertical, or nearly so. The column, in shallow water, goes very high, but is correspondingly thin. With a considerable depth of water over the charge the column is, however, broad and low. This column of water has, besides immense weight and considerable velocity, an absorbing force, owing to the partial vacuum that its upheaval causes below. This motion is followed by a corresponding sinking of the surrounding surfaces, and after that comes the second or minor upheaval, caused by the return gas from the bottom. This is generally a small column of mud and water, and is only apparent in the case of charges fired in depths greater than six fathoms. In the case of a rocky bottom such a movement would not occur, as the upward motion of the portion of the gas that acts on the bottom would be coincident with that of the rest. The sketch (Fig. 10, Pl. III) will perhaps better explain the movement of the surface and the action on the bottom. It represents the action of a charge of 1,750 lbs. of powder exploded in water 45 feet deep. The alteration of the bottom was in the form of a basin, and was accurately measured by soundings after the occurrence. The difference of soundings in the middle, allowing for rise of tide, amounted to 8 feet, and the disturbance extended for 24 feet all round.

The action of a charge of powder laid on the bottom, in water not exceeding eight or nine fathoms in depth, is effective in the case of a vessel immediately over it; but when on one side, and the charge not very large, the vessel will suffer a concussion only, and that not very severe. In order to increase this concussion the Confederates employed immense charges, so as to injure vessels when out of the real sphere of explosion. There is also an intermediate result between entire destruction by a large charge when exactly under the vessel, and the concussion produced by the same when 20 yds. or so beyond, and that is the strains and injuries produced by the commotion of the surface and the partial action of the column on the hull of the vessel. The force thus exerted on the vessel is not to be compared to that of immense waves, but it has the inertia of the rest of the vessel to assist it, as the movement only affects a portion of the vessel. There is besides the possibility of the boilers bursting when the vessel receives such a shock, and this quite compensates for the inaccuracy of the position of the vessel with respect to the charge. But as I have before remarked, this plan depends on the indirect action of the mine, and consequently a proportionate increase of the charge has to be made even to a point where the quantity of powder becomes scarcely manageable.

A detailed account of the blowing up of a gunboat called the "Commodore Jones," will probably illustrate some of the difficulties of submarine mining. In the beginning of May, 1864, Admiral Lee prepared to ascend the James River, being in co-operation with General Butler, who had a few days previously landed at Bermuda Hundred, with the intention of advancing on Richmond. The Admiral, suspecting the river to be mined, caused it to be searched and dragged, also the banks examined. The latter was easily effected in the absence of the Confederate Army, which was then falling back on Richmond after the battle of the Wilderness. The tedious process of dragging reduced the progress of the fleet to little more than a mile each day, and on the 6th of May the fleet arrived at the bend above the Curl's Neck (vide Pl. I). The Admiral knew, by information received from some negroes, that at the point of the bend near the Curl's Neck, the Confederates had dropped two mines, and that the mining stations were on the left bank. Captain Davidson had anticipated this, for on the night of the 5th he dropped down the river in a boat, with two men only, and removed the wires and battery over to the opposite shore. Here the ground was low, marshy, and covered with reeds. Pits were dug, and, although half filled with water, the men were left in them. The mines lay in a part where the channel for large ships was only 150 yds. across. Each mine was 1,750 lbs. of powder, and the depth of water 45 feet. Their distance apart was 50 yds. When the Admiral came within 300 yds. of the bend he stopped the fleet, and ordered the boats to lie by their vessels in readiness for dragging. The double-end gunboat "Commodore Jones" (800 tons), was then sent to reconnoitre. She passed over the mines and went round the bend to the landing, which was half-a-mile higher up, and then returned to the fleet, nothing having been observed. In the mean time the troops on shore had discovered the abandoned range station, where an old battery, wires, clothes, and muskets had been purposely left in a state of confusion, in order to lead the enemy to believe that the miners had retired altogether. The Admiral then sent the "Commodore Jones" round the bend again, and shortly after it passed the mines it was recalled, by an order given through a speaking trumpet, to the effect that "the gunboat was to return and let the boats go ahead and drag." This order was distinctly heard on shore, and shewed that no time was to be lost. Captain Davidson had therefore to give up all hopes of destroying the Admiral's vessel, which was a fine one, and had to content himself with the gunboat; so, on the "Commodore Jones" approaching the line on the way back for the second time, he gave the preconcerted signal from his side of the river, and when the vessel crossed, *the circuit was closed* for the mine on the left. On the explosion taking place, the gunboat appeared to rise and then bend a little in the middle. The movement was followed almost immediately by the explosion of the boilers, which sent everything into the air. The explosion must have been an awful sight to witness, for the air seemed filled with burning bodies. This, to a certain extent, was the case, for all the crew were blown up with the vessel, but their (apparent) number was enormously increased by the stores of clothing that happened to be on board being set on fire and driven about by the explosion. The affair was followed by a most remarkable stillness, only broken by the splash of the falling bodies and fragments. Not a sound was to be heard from

the Federal fleet, and this continued for a few minutes. At length all the vessels put about and hurried away to a reach lower down, running foul of each other in the narrow channel, in the anxiety to get clear of the scene of disaster. The officers and crew of the gunboat numbered 151, and the greater portion were killed outright. Twenty were removed to a hospital, of whom only three survived, and these had probably been thrown into the water. It is a remarkable fact that all the bodies that were not mutilated by the explosion, proved, on examination, to have the vertebræ broken low down. It was supposed to have been occasioned by the first shock from the mine. The Federal fleet having recovered the confusion, boldly advanced again to the end of the reach in which the mines were, and men were landed to search the low shore on the right bank, which, from it being a marsh, and from its apparent openness, had not been before suspected of concealing such a mortal enemy as a *torpedo man*. On the Marines advancing, the man in charge of the battery tried to escape from his pit: he was pursued and bayonetted. The observer who had made the connection was discovered at the range station and surrendered. The soldiers, in their indignation, were with difficulty restrained from treating him in the same way as the other man, but eventually he was made a prisoner of war. This man was a sturdy farmer from the neighbourhood, and when corresponded with afterwards, while in prison, for the purpose of ascertaining his motives for staying so long at the range station, he confessed that he had waited to give the Admiral's vessel the benefit of the contents of the tank on the right. This is a rare instance of cool determination, and there is no doubt that in the hands of such men as were employed on this operation, submarine mining will always succeed.

The blowing up of a vessel similar to the "Commodore Jones," viz., the "Commodore Barney," though a partial failure, is not less interesting and instructive. This gunboat, commanded by Lieutenant Cushing, United States' Navy, went up the James River in the latter part of August, 1863. It was unopposed until it reached Cox's Ferry (vide Pl. I). At this point there were two mines of 1,750 lbs., placed 50 yds. apart, and with a depth of water amounting at high tide to 46 feet. One of these was exploded, and an immense column of water thrown up 45 yds. in advance of the vessel. It appears that the officer at the range station in this case closed the circuit too soon, through nervousness; but notwithstanding, the vessel was not let off, for its speed, at the time, being at least nine knots, it ran into the column, and came in time for the second upheaval, or one with mud from the bottom. The large column of water in its descent came on the vessel, overturned the guns, and washed overboard the carriages and every thing loose; it also stripped the mast clear of all rigging. The gunboat certainly got away, but the framing had been so loosened and distorted, and the planking so opened, by the knocking about the vessel had received, that it could with difficulty be kept afloat. This case has been ridiculed by the Federal journals as an instance of the slight effect of mines; but for a failure it may be considered highly satisfactory, as the gunboat was never used again, the injuries being of such a nature as to be beyond the power of shipwrights to remedy, without taking the vessel to pieces and rebuilding her.

Precautions against Mines.

Having explained the different kinds of stationary and drifting torpedoes employed by the Condeferates, it will be necessary to describe the precautions of the Federals against them. After the first surprises occasioned by the use of torpedoes, the Federals naturally kept a sharp look-out, and moved in suspicious places with the utmost caution. With drifting torpedoes, nets hung round a vessel, or spars in the water when at moorings, kept off this kind of machine effectually. With detonating torpedoes, moored a little below the surface an outrigger of small spars, fixed to the bows, proved a sufficient safeguard, as it exploded the torpedoes harmlessly, in advance of the vessel. In cases where this kind of torpedo was employed in numbers, a careful search was always made if possible prior to an advance. Their moorings were grappled for, and the machines themselves fished up by a kind of scoop worked from the end of a boat. After some time the Federal seamen became such adepts at this kind of work that they could, if undisturbed, clear a channel of torpedoes. They managed also, now and then, owing to the lightness of the moorings, to take up torpedoes at night, within range of batteries, without attracting attention. The facility with which the small torpedoes were neutralized or removed, led the Federal sailors to regard them almost with contempt; but their feelings with respect to the large mines at the bottom were of a totally different character. When a river was known to be well mined, and information could not be obtained as to the parts where they lay, the Federals made their advances in a most careful manner, dragging the river and searching the shores. The advance, in cases where there were no batteries or troops to oppose it, was headed by the boats of the fleet with grapnels astern. Next came the gunboats with two large grapnels dragging behind each. Then followed the iron-clad vessels, and the wooden vessels brought up the rear. On the banks were Marines who advanced evenly with the boats, in skirmishing order, and examined every bush or break, passing their bayonets through them or firing into them, when they looked likely places for concealment. This was done to find the range stations and the observers, with the view of cutting the wires. On one occasion at Deep Bottom, on the James River, when the mines were twelve miles in advance of their supports, the Federals, who had information as to the general position of the mines, approached them, and fired a grapnel from a howitzer across the line of the mines several times and then dragged backwards, but the wires were not disturbed, nor the exact position of the mines discovered, and this caused the advance to be abandoned for the time.

Dummies.

To render the search on shore as difficult and tedious as possible, the Confederates employed ruses, such as the construction of sham stations and the laying of false wires. These they buried deep, and led them through the roots of trees. The ground was also broken in different places, and deep trenches cut and filled in again, in order to appear as if used for the wires. The tanks were always dropped with the greatest secrecy, and their position was only known to a few of the Torpedo Staff; but on some occasions solemn preparations for mining were made openly. The mines laid were either dummies or real ones, which would be lifted again at night and placed in their true position. The trap generally took, for the position was sure to be notified to the enemy by some friendly negro. Dummy mines and false information were freely employed by the Confederates. On one occasion, when the Federals were

about to send a flag-of-truce boat up the James River (Pl. I), Captain Davidson gave the Officer in charge (formerly one of his comrades) a mysterious caution about passing the Curl's Neck, something in the Lord Monteagle style, only the danger in this case did not prove so real, for Admiral Lee's fleet, after dragging that part of the river carefully for five days, brought nothing dangerous to light.

Torpedo Boats. Motive torpedoes are small mines fixed at the end of booms attached either to boats or specially built vessels. This is a totally different application of torpedoes to what I have already described. With any kind of stationary mine one has to get the enemy's vessel to approach her fate, consequently in the matter of absolute destruction there will always be an element of uncertainty; though in effectively keeping the enemy at a respectful distance, and demoralizing one's opponents, such mines may perform their *rôle* most perfectly. But when torpedo boats are employed, the vessels of an enemy at night, off a port, or in a roadstead, or anchored near shore, can never be entirely safe. By the use of them, destruction is brought up to the enemy's door, and as contact is one of the conditions, there is no difficulty in providing an effective mine. To get the boat up to the enemy is the great point, and for this cool pluck and steady nerves are required. The principal torpedo boats employed by the Confederates were originally ships' gigs. They were good sea boats, fast, and with fine lines. Their length was 30 feet, beam 6 feet, and they drew 3 feet of water. To fit them as torpedo boats, a single cylinder engine to work a small screw propeller was fixed in them. The single cylinder was chosen, for space in such small boats was of great importance, and double cylinder engines, fitting into the same space, could not be then obtained in the Confederacy. The supply of fuel was close to the engine, and the coal employed on torpedo expeditions was always anthracite, on account of the large supply of steam it produces and its smokeless nature. Over the engine was fitted a cover, like that of a gondola, only rendered to a certain extent shot-proof by being plated with three inches of iron. In the fore part of the boats was a curved bullet proof shield, with its front and side edges hollowed out, to allow of the course being observed from under the shield. The shield also covered the steering apparatus. The boom was made of spruce pine, 20 feet long and 4 inches thick at the socket end, increasing to $5\frac{1}{2}$ inches, six feet further on where the strain would come, and then tapering to 3 inches at the end. To insure a horizontal thrust with the torpedo, when lowered, the end of the boom was curved upwards. This was effected by sawing it down the middle for 5 feet of its length, and riveting it, when bent, to the desired curve. For the fixing and movement of the boom, a fork made with two iron arms, 6 feet long, welded together at the apex, and provided with a stout socket, was attached to the sides of the boat, and made to pivot on bolts, so that the socket came a little in advance of the cutwater. A chain from the socket was passed over a roller fixed at the bows of the boat to the shield, from under which the boom could be depressed or raised. The torpedo employed was a charge of rifle powder in a copper case made of the shape of a magnum champagne bottle, but with a round end. The head of the boom was passed up the neck and retained there by a pin. The end was provided with five detonators, like those already described, and arranged in such a way that, however obliquely the torpedo boat might be rammed against the side of a vessel, one detonator at least must act. When the torpedo was fixed, the

boom was always lowered until it rested on the water. In this way the weight was diminished and vibration checked, but on approaching a vessel the boom was inclined downwards. The depth would depend on whether the vessel to be rammed was plated or not. For an iron-clad, 8 feet below the water would be necessary. The special fittings of the torpedo boat were all made moveable, and when these vessels were not required in a dangerous capacity the fittings were removed.

Charges. For the determination of the charges, the length of the boom, and action on the torpedo boat, a series of experiments were made near Richmond against 10-inch piles, bolted and braced together, planked on both sides with 4-inch stuff, and filled in, to represent the side of a very strongly-built ship. The charges employed were 55 lbs., put in copper cases with detonators at the ends. The torpedo boat was driven at the rate of three knots an hour, and the piling rammed first at 3 feet below the surface, and deeper in succession, down to 8 feet. At 8 feet below the surface, the piles directly exposed to the action of the charge were cut completely off, and 20 superficial feet of planking driven inwards. At 7 feet the damage was the same, but the *débris*, instead of being driven in, came to the surface. At 6 feet the piles were only displaced, and the planking ripped off, the water in this case being thrown up to a great height. At 5, 4, and 3 feet the damage produced became less and less, while the column of water went higher. The natural deduction was made that a superposed weight of water is necessary to produce the full effect of a charge exploded against the side of a ship, and that the mine should be lowered 7 or 8 feet below the surface in all cases. In the experiments for recoil, as much as 75 lbs. of powder were fired at a depth of 6 feet. It is probable, in this case, that the whole charge was not ignited, but whatever the charge may be, a lesser depth should be avoided as the reaction on the boat becomes much too great.

Before alluding to other kinds of torpedo boat arrangements, I will relate a case in which a torpedo boat, such as that I have described, was used. The case occurred with the "Minnesota," when laying in Hampton Roads, off Newport News, on the night of the 9th April, 1864. The boat employed in this instance was called the "Squib." It was a good sea boat, manageable and capable of going nine knots an hour. The charge at the end of the boom was 55 lbs., with acid detonators fixed in the end of the case. On the night in question, Captain Davidson, with the engineer of the "Richmond" and another man, dropped down the river in the "Squib," with the intention of destroying one of the large Federal vessels, and, if possible, the Admiral's vessel the "Minnesota." They first approached the "Atalanta," but it was too near the shore, and surrounded by boats, so they made for the next large vessel, which proved to be the "Roanoke." But neither with this vessel could ramming be attempted, for she was coaling and surrounded by barges at the time. The "Squib" was hailed, and Captain Davidson replied that he carried dispatches for the Admiral from Fortress Monroe. He then obtained information as to the position of the "Minnesota," and steamed off in search. The moon was up, but the passing clouds obscured it, so that the vessels were difficult to find. I must add that there was a little sea on, sufficient to make the torpedo boat very wet, but for all that she carried her boom, with the torpedo resting on the surface of the sea,

without any danger from vibration. Captain Davidson, on his way to the "Minnesota," was hailed from a double-end gunboat. He replied as before and went on, sparing the gunboat on account of her small size. On approaching the "Minnesota" he was sharply hailed, for a good look-out was always kept. On answering, he was told to deliver his despatches on board the tender, which was astern of the "Minnesota." In place of doing this, he shot under the bows of the vessel and circled, so as to ram her on the starboard side. The officer of the watch seeing this, cursed Captain Davidson for his stupidity, and told him that he was running into the vessel. When too late the officer discovered the character of the stranger, and shouted out "Torpedo boat." Captain Davidson then said, "This is the Confederate States' torpedo boat 'Squib,' and go to ——;" following up the information by striking the vessel. The vessel was rammed 8 feet below the surface of the water and close to the screw alley where the hull is strongest. By the concussion the screw shaft was thrown out of centre, fourteen guns on the main deck were dismounted, and some of the sailors were thrown out of their hammocks. In the mean time the "Squib" was in difficulties, for it could not get away, as the concussion had caused the shaft of the single cylinder engine to hang on its bearings. Some of the Federal sailors and Marines recovered their surprise quickly, and fired several bullets into the boat, and some guns from the broadside were also fired, but the proximity of the "Squib" to the ship saved it. At length the engineer worked the shaft round by hand and got the engine in motion again. In this way the boat got off clear, for, in some miraculous way, the shot missed her, and the tender not having steam up, pursuit was out of the question. Favoured by the darkness, Captain Davidson got back to the river again, but for the first mile his boat acted the part of target for the Federal vessels near, the gunners being guided by the sparks from the funnel. The "Minnesota" did not sink, and the failure to breach the side of the vessel was assigned by Captain Davidson to the fact of chemical fuzes* having been used. The time for the union and action of the chemicals, though short, must have allowed the recoil of the boat, after impact, to place a distance of 3 or 4 feet between the charge and the side. This is sufficient to account for the charge not perforating the side; the damage done was, however, considerable, for the seams of the planking were so much opened about the part struck that the vessel could not be kept free from water with the ordinary pumps; and only by the use of two large pumps sent on board shortly after the occurrence, could she be kept from sinking before getting her into dock.

The Confederates applied booms to almost all their vessels in the James River, and, at the close of the war they were having constructed some light torpedo boats made with steel plates and fitted with proper engines.

The use of torpedo boats was not confined to the Confederates. Mr. Wood, Inspector of Steam Machinery in the United States' Navy Department, and Chief or Professor of the Engineering and Torpedo Branch at the Naval School of Annapolis, invented a boom arrangement and a torpedo shell of a peculiar kind. His system was applied during the war to small picket boats about 45 feet long, with 8 feet beam, carrying one gun at the bows, and with them the arrangement was external, the boom being fixed to the side of the boat. The

* A tube or phial of sulphuric acid, surrounded by chlorate of potash and sugar, mixed together in equal quantities, was employed on this occasion.

boom in Wood's plan is hollow, and contains a smaller boom or rod (vide Fig. 14, Pl. III). The whole is advanced and depressed by machinery on board, as required; the internal rod, by which the torpedo is held, is advanced with the boom, but is capable of being pushed out or withdrawn independently, to a certain extent. The torpedo is a case containing the charge of powder with an air chamber to give it buoyancy (vide Fig. 13, Pl. III). At the top is a pin that retains a ball, and under that, near the base, is a cap with some fulminating compound. On approaching a vessel, the boom is to be thrust out and depressed, and on coming in contact with, or passing alongside the vessel, the rod has to be withdrawn. This, by some arrangement, liberates the torpedo, and pulls a line attached to the pin, letting fall the ball on the cap. In the first-made torpedoes of this kind, the valve for the ball was at the side, but in the improved ones (vide Fig. 16, Pl. III), the valve is in the middle, and the cap screws in at the bottom, so that the priming can be delayed until the shell is required for use. In all cases the air chamber is so shaped as to make the shell float with the pin side upwards. The whole plan is very ingenious and admirably suited to the destruction of vessels with overhanging floors, such as most of the American vessels had; for the torpedo, on rising, could not fail to come in contact with the projecting part. But with a vessel built in the ordinary way, contact at the moment of explosion would be uncertain, unless the torpedo is worked from the tide or current side.

With a boat fitted in this manner, and commanded by Lieutenant Cushing, of the United States' Navy, the Confederate vessel "Albemarle" was destroyed in 1863, as she lay off Albemarle. He ran into her, letting loose and exploding the torpedo himself. The projecting side of the vessel was ripped open and the vessel sank in twenty minutes. His picket boat, however, received a raking shot and sank as well. All hands were killed or taken prisoners by the Confederates, except Lieutenant Cushing, who swam ashore and escaped in the marshes. This was all done in daylight, and is one of the most daring and gallant acts of the war.

The Federals afterwards built a small vessel expressly for torpedoes, called the "Stromboli." The name was afterwards changed to the "Spuyten Duyvil."* The vessel is 74 feet long, 20 feet in the beam, and draws in her ordinary trim 7 ft. 5 in., and when immersed for action, 9 ft. 1 in. The tonnage of the vessel is about 130. The vessel is provided with compartments, into which water can be let to sink her to the deck line. The deck, which is the only part above water when immersed for action, is 2 feet thick, and plated with 3-inch iron. In the middle is the pilot-house, which is strongly plated, and stands 38 inches above the deck. This, and the funnel, is all that is exposed. The torpedo arrangement on board is Mr. Wood's (vide Fig. 13, Pl. III), and is worked from inside the vessel through a compartment in the bows secured by a slide and cut off from the outside by lowering a gate. This arrangement puts the whole under cover and renders the working safe. The engines are so constructed as to be noiseless, and this, added to the small show the vessel makes on the water, would cause her approach to be difficult of detection; but if observed, her appearance, unlike the Confederate torpedo-boat, would immediately betray her real character.

* *Spuyten Duyvil* is Dutch. There is a creek near New York called by that name, and being appropriate, the torpedo-vessel was named after it.

During the latter part of the war the "Spuyten Duyvil" was ready for use, but no occasion arose for her employment. After the war she was actively engaged in removing the formidable obstructions established by the Confederates at Drury's Bluff, on the James River, and in other ports and rivers, by means of torpedoes dropped close to the cribs, piles, or sunken vessels.

Submarine Boat.

The Confederates once made use of motive torpedoes under water, and so destroyed the Federal sloop of war "Hoosatonic," off Charleston, in December, 1863. The boat employed had been used in the harbour for diving, and was constructed specially for locomotion under the surface. With this object the boat was entirely covered in, and when submerged, communication with the surface was only maintained by means of an anti-collapsing India-rubber tube. The crew was also supplied with compressed air from tanks, and locomotion was effected by means of machinery worked by hand. When manned and loaded, the boat had only 50 lbs. floatation, and the submerging was easily effected by letting in water. The torpedo it carried was fixed on the end of a boom lashed to the flat deck or covering. In the case I refer to, the little torpedo boat started on its mission, and rammed the Federal sloop of war "Hoosatonic" on the quarter. The stern was nearly blown off, and the vessel settled down quickly. From this one must conclude that the ramming was successful. The little boat, however, did not get back to tell its own tale, for, on its return, it was destroyed by the breakers on the bar of Charleston. This plan was always regarded by the Confederate officers with doubt and misgiving, for the boat was uncertain in its motion, and could not be easily manœuvred; besides, on former occasions, when used for diving, accidents from suffocation had frequently occurred. It was also feared that, after ramming a vessel, the convulsion of the water would seriously affect it and drive it down.

Instances of employment of Torpedoes.

Having now given, as far I am able, accounts of the different kinds of submarine mines used by the Confederates, and the manner of applying them, there remains to be indicated the effect torpedoes had on the war. The absolute number of Federal ships destroyed by the Confederates was *thirty-nine.* This does not include the two or three that received such injuries that they had to be docked for repair. Some of the vessels were gunboats, and transports or store vessels, but out of the number eleven were fine war vessels, and they alone would form a respectable squadron. The effect of torpedoes is not, however, to be measured by the direct loss inflicted on the enemy, but by the long delays occasioned through them, the advances checked, and the raids up rivers prevented. In such a war as that carried on between the Northern and Southern sections of the American Union, it would be impossible to trace all the mining events and their bearings on the movements; but a few will suffice for my object.

The saving of the Welden rail communication in December, 1864, is a notable instance. General Grant, then before Petersburgh, had broken up part of the track close to his left, but General Lee, who covered the rest of the rail with his army, was still able to draw his supplies from Wilmington, by taking them across the country in waggons at the part where the line had been destroyed. The Welden line being the grand artery of communication to Richmond, along which the chief portion of the supplies and blockade-run stores were drawn, its complete interruption was necessary for the carrying out of

General Grant's plan of starving his opponents. With this object nine gunboats were sent up the Roanoke, to burn the bridges at Welden, where the rail crosses the river sixty miles south of Richmond. The squadron of gunboats nearly reached their destination, when four of their number were destroyed, and three severely injured by detonating torpedoes. This effectually stopped the expedition, and the bridges were saved. The check was produced by the torpedoes alone, for they were unsupported by troops or batteries. I must add that the Federals were provided on this occasion with appliances for lifting torpedoes, and advanced carefully, as they knew that the river was mined.

In the latter part of April, 1864, General Butler landed at Bermuda Hundred, (vide Plate I), in the rear of Petersburgh. He was to advance on Richmond with his right covered by Admiral Lee's fleet on the James River; but he was delayed there five days, owing to the slow advance of the fleet while searching the river for torpedoes. The blowing up of the "Commodore Jones," on the 6th of May, completely checked the progress of the fleet, and when General Butler advanced and attacked the intrenchments at Drury's Bluff, expecting to find there a weak force, he was repulsed; for on account of the naval attack not occurring at the same time, all the men in the river batteries, there and at Chaffin's Bluff, were available for service in the land line of intrenchments. The little delay of five days also gave General Lee time to throw a garrison into Richmond, the force there having been reduced to a few hundred militia at the time of his advance prior to the battle of the Wilderness. The thrusting in of a division between Petersburgh and Richmond before the main Confederate army could fall back to cover the capital, while the garrison of Petersburgh was held in check by the fear of the advance of the Federal army, was one of the boldest pieces of General Grant's strategy, and deserved success; but, by the agency of submarine mines, the movement was rendered abortive and the most disastrous consequences to the Confederacy averted for the time. It is, however, possible that, had less reliance been placed on the fleet, the advance on the Confederate capital and its capture when almost denuded of its defenders, might have been effected according to General Grant's plan. But, nevertheless, the fact that submarine mines saved Richmond, at this particular time, remains the same.

Off Fort Fisher a few mines to be fired by electricity were laid in the Cape Fear River prior to the bombardment, to bar the passage to Wilmington. Dummies were also freely used. All these, together with the shifting of the shoals, which during the war had caused the channel to become unknown to the Federals, kept the large ironclad vessels from running past the fort; but the existence of torpedoes alone prevented Admiral Porter from sending his light draught vessels round the fort to take the batteries in reverse. Consequently, the Admiral was obliged to attack Fort Fisher, and at a disadvantage, for he was forced to take up a position for the bombardment opposite the strongest part, and where his ships were somewhat under the influence of the roll of the Atlantic.

At Charleston, torpedoes were laid in different parts of the harbour. Most of them were detonating torpedoes of a very inferior kind, and many were dummies; but their moral influence could not have been greater. It was owing to their presence, together with that of some very imperfect surface obstructions,

that the Federal ironcased fleet did not try to run past the batteries. The severing of the communications between the Federal forces at the mouth of the St. John's River, in Florida, and the troops in the interior of that state, by the means of torpedoes, and the subsequent withdrawal of the force, I have already mentioned in the early part of this paper. Several other raids up rivers were checked in the same way.

In April, 1865, at the attack of Mobile, by Admiral Lee, the Federal gunboats, Milwaukee, Osage, Laura, Ida, Iberville, Blossom, Rover, Scotia, and No. 48, were destroyed by torpedoes arranged in advance of Spanish Fort. The fort relied almost entirely on the submarine mines for protection; in fact, too much so; for, although the mines did their work, the Federal vessels ultimately passed the line and took the fort; and in consequence the city surrendered. This case shews the necessity of having a second or even a third line of torpedoes; for a determined enemy might, by sacrificing some vessels, get through a single line.

Employment of Torpedoes by the Federals.

On considering the many cases in which the Confederates successfully employed torpedoes, it seems strange that the Northerners, who are so ready and quick at taking advantage of inventions, should have been in a measure slow to avail themselves of the use of torpedoes. Early in the war the Monitors had fitted to their bows a frame or raft which carried a shell at the end. The frame was arranged so that it could be raised or lowered, and the torpedo shell was to be fired by a trigger and line. Besides having the disadvantage of not being able to repeat the explosion, the arrangement made the Monitors, when in a narrow channel, almost as dangerous to friends as to foes. Ultimately this plan was discarded, but experiments in other directions were continued. Much time and money were expended on trials of rocket torpedoes, but the idea of employing them was abandoned on account of their deflection by any motion in the water; for they went in and out of the water like a flying-fish, and twisted about in the wildest manner imaginable. After this came Mr. Wood's invention, which, applied to a picket boat, was used in Cushing's memorable exploit against the Albemarle. This was the only successful case of retaliation on the South by means of submarine mining. It must, however, be remarked that shortly after the Federals had fully recognised the advantages to be derived from the employment of torpedoes, the sea-board of the Confederate States had been cleared of ships. Some had been destroyed, but many of them were confined in the Southern ports and rivers, and the remaining few kept to the ocean. Towards the close of the war the Federals built some torpedo rams, and on the James River they mined the reaches near their batteries and obstructions. They also laid down in the bed of the river some tanks that they had captured in an advance; but when Brook's fleet came down the river, these particular mines were worked in vain against the Confederate vessels. This shews that the Federals had not at that time a properly organised torpedo staff. The want of good electricians was, however, subsequently, supplied: for in February, 1865, quite at the close of the war, some very able electricians were sent down from New York. Several of the officers with the army were fully alive to the importance of using torpedoes and experiments were made during the war, near the Washington lines, by the help of the Telegraphic Corps. Shells fired by electricity were tried, and some

torpedo shells were also exploded from a distance in some of the advanced rifle-pits; but I never could get any confirmation of the report that they were used during an engagement. At the close of the war, after Lee had surrendered, torpedo shells were extensively employed for the removal of obstructions in the various rivers and ports of the Confederacy, in order to permit of the passage of the Federal fleets. The Northern Americans have, however, since the war, made up for their partial indifference to the advantage of employing torpedoes. They have lately equipped five large vessels with torpedo arrangements, and are building some small rams. In time the adaptation will be general throughout their naval service. On shore they are not less active, for the museum of *rebel* torpedoes is carefully studied; and experiments are carried on for the investigation of the laws relating to submarine mining, and the reduction of it to a system. These experiments are made privately, and the results are not allowed to be published, but are the subjects of confidential reports. There is also at the Naval School at Annapolis, a regular class for torpedo instruction, and several officers of experience are engaged in working up the subject.

Land Torpedoes.

The first land torpedoes employed by the Confederates were shells with detonators fixed in them. These detonators were made of a composition calculated to go off under a pressure of 8 lbs., in fact the detonators were made precisely like those I have already described in connection with the torpedo boats and stake guns. The shells, however, proved clumsy, and went out of fashion. In their place canvass bags, filled with bullets and scrap iron, were used (vide Fig. 11, Pl. III). In the middle was placed the charge in a canister, made strong at the top, where the detonator was fixed. The charge was 8 lbs. of powder, and these torpedoes were arranged in front of some of the Confederate intrenchments and forts, in small pits, and covered over with sods or loose earth. The pits were dug in such a way as to cause the line of least resistance to be towards the enemy. The distance that these torpedoes were placed apart was generally 30 ft., and their position indicated by little red flags, which were always taken up when an attack was expected. This kind of torpedo was used on the left of the Petersburgh intrenchments, and at longer intervals at the points likely to be assaulted. Similar mines, on an extended scale, were also employed. These latter were carefully arranged (vide Fig. 12, Pl. III), with larger charges to be fired by electricity, and the wires were led well below the surface into the works in rear. A sheet iron tank, 4 feet long by about 3 feet broad, and 10 inches deep, was used to hold the scrap iron. The receptacle for the charge was a case of sheet iron with a very heavy base, and a strong cap of cast-iron connected together by a stout spindle. When the charge exploded, the light sides of the case were blown out, and the top, which was retained in its place by the spindle and base, gave a nearly horizontal direction to the contents of the tank. This kind of mine was never put in operation, as the Federals never approached it; but from an experiment made in the woods near Petersburgh, where screens were erected to represent troops advancing near the site of the mine, the effect must be very great, for the screens were riddled, and the trees within 50 yds. were barked and cut about. This mine is really a development of the Stone Fougasse, but vastly more destructive. Like the submarine mines, these scrap-iron land torpedoes had great

moral effect. The Confederate intrenchments of Petersburgh on the left were, during the latter operations of the war, provided with them, and such was the protection they afforded that only two companies per mile were sometimes left to hold the works in rear of these torpedoes, the rest of the corps having, from necessity, been withdrawn to the centre and right, where the hard fighting was expected. It is fortunate that torpedoes were used, as it permitted of the abstraction, without very much weakening the line. Elsewhere dummy mines were frequently established in advance of some of the Confederate field-works; but I have not been able to find any particular instance of the actual mines being exploded against the enemy. The fact that such mines were never passed over by an assaulting column proved that they did their work.

At Fort Fisher regular mines were laid along the beach, over which the Federal troops had to pass for the assault, but in the final attack they miscarried. The Federal shot and shell ploughed up the ground and cut some of the wires, for they had been buried only 3 feet deep. At the time, this reason was alone assigned as the cause of the failure of the mines, but it was afterwards discovered that the fuzes had been spoilt, for the Federals, on taking up the mines, could not explode the fuzes, the wires to which had remained intact. The mines were laid 30 feet apart, with single wires, and were arranged to be fired by one of Wheatstone's magneto-electric exploders, that had been obtained from Captain Maury through some "blockader." This was almost the first time that the exploder had been used by the Confederates for mining purposes, and the non-completion of the experiment was a source of great disappointment to Captain Pembroke Jones, the officer then in charge of the mining operations. There is no doubt that had the mines on the shore been in perfect order, the advance of the Federal column would have been checked, and the soldiers would have been disappointed in their keen desire to prove that General Butler was wrong in his estimate of the strength of the works. The capture of the fort could, however, have been deferred only for a time. At the river end of the fort the torpedoes in the channel had been rendered abortive through the 40-cell galvanic battery, having been established without splinter-proof shelter, for the great 40-feet traverse, under the cover of which it was to have been worked, was destroyed by two 15-inch shells, and the battery buried in the falling sand. The safe covering of batteries, deep trenching for wires, and caution in testing, are three lessons to be learnt from this affair at Fort Fisher.

Land torpedoes are very simple and are easily established. With them a cordon can be drawn round a fieldwork or battery, or even a part of a position, that would not be passed by the bravest troops. They are readily improvised, and, even when they cannot be made for want of means, the breaking of the ground at intervals, and the establishment of the little red flags, would be almost as effective, provided that the secret be well kept, for the fact of some preparations having been made would soon be communicatated to the enemy by deserters.

The methods used by the Americans in the employment of torpedoes during the late civil war, may be, in a measure, imperfect in many details; for superior appliances have since been invented, but it must be remembered, that prior to this war the knowledge of the employment of torpedoes against an enemy was

next to nothing. To understand the extreme energy and labour expended in initiating the system of torpedo warfare, the fact that proper stores and instruments could not at first be obtained in the South, should be known. In consequence of this deficiency, many articles which had been previously obtained from Europe by way of trade, had to be then manufactured for the first time. When these difficulties had been surmounted, and supplies of improved appliances and stores had been received in the Confederacy from the Confederate agents in Europe, the employment of torpedoes improved rapidly, and very extended operations were about to have been undertaken, when the war ended suddenly and put a stop to them. The Confederates have been reproached with making war in a barbarous manner. Submarine mining is, after all, only a branch of military mining, though perhaps a new one, so more should not be said against one than the other. I suspect the morality of different kinds of mining to be about equal; for when a number of men are destroyed by hidden charges of powder, it is immaterial in what element the mine may have been worked. The Confederates sink a vessel or blow one up with its whole crew, and the world regards such a mode of warfare as very reprehensible. General Grant springs a mine under the Confederate intrenchments and Petersburgh, and launches several hundred men into eternity; but as this is considered a legitimate part of warfare, nothing is said against it. A difference of feeling towards the two great branches of mining may, however, be traced to the fact that one has been a long established custom in the attack of fortified places; while, on the other hand, effective submarine mining is perfectly new to us all.

E. H. S.

November, 1865.

PAPER II.

MILITARY SKETCHING, REPRESENTATION OF GROUND, &c.*

By CAPTAIN WEBBER, R.E.

In beginning this paper† I need not repeat the points which I conceive may be worthy of being discussed by this meeting, but I shall read them successively in prelude to my remarks under each head.

But, *first*, I would say to those who advocate the wholly *pictorial systems* of representation versus *uniform scales*, that I did not refer to them in my paper in Vol. XIV, Professional Papers, because Lieut. Col. Scott had already handled the principles involved in the consideration of both sides of the question in his paper contributed to Vol. XII of the same series. Nor shall I include any proposition for a further discussion on these principles in this paper.

For myself, I cannot conceive any one who has seen, and proved, himself, the results of the use of uniform scale, advocating any other system; and I hope that the results I shall be able to shew this meeting will be of such a nature as to induce many to endorse that opinion.

1. *Analysis of some of the scales of shade that have been proposed.*

In the following table, the relative value of black to white at 45°, differs in 2, 3, 4, and 5, considerably from that given by 1, in which the deprivation of light is *in proportion to the increase of area of the plane receiving it,* the numerical value of the black being equal to the secant of the angle minus one.

Lehman completely blackens a plane at 45°, because it ceases to reflect the vertical rays at that angle towards the observer.

In the French scale, the proportion of black to white at 45° is obtained by an arbitrary rule.

In Lieut. Colonel Scott's, it is obtained by drawing strokes as close as possible to one another, with a thickness which he has determined by micrometric measurement of lines in good specimens of hill sketching.

In my scale, the thickest strokes that can be conveniently made with a medium etching pen, are drawn as close to one another as possible, which distances I have made less than Lieut. Colonel Scott.

The proportion of white to black, at 2°, varies considerably.

At the highest angles, Lieut. Colonel Scott's approximates to the French, mine to the German.

* A Paper read at a Meeting at the War Office, May 12th, 1866.

† For introduction to this subject, see Paper XVI, Vol. XII, and Paper VIII, Vol. XIV.

At 10°, the black is as 25, 23, 20, and 12, in 5, 2, 3, and 4 respectively, No. 5 being double No. 4.

At 5°, the proportion of black in the German, French, and mine, nearly agree, being double that in Lieut. Colonel Scott's.

In the angles below 5°, the value of the black decreases much more rapidly in mine than in any of the other scales.

TABLE shewing proportions of black to white at various angles on any unit of area on plan.

Degrees	1 True Scale.		2 Lehman's Scale, German.		3 French Scale.		4 Lt. Col. Scott's.		5 Capt. Webber's.	
	Black.	White.	Black.	White.	Black.	White.	Black.	White.	Black.	White.
45	·414	·586	1	0	·6	·4	·708	·292	·803	·197
35	·22	·78	·78	·22	·512	·488	..	..	·724	·276
25	·103	·897	·56	·44	·38	·62	·339	·661	·55	·45
20	·064	·936	·45	·55	·35	·65	·255	·745	·455	·545
15	·035	·965	·34	·66	·286	·714	·189	·811	·338	·662
10	·015	·985	·23	·77	·209	·791	·126	·874	·25	·75
7	·0075	·9925	·155	·845	·155	·845	·083	·917	·173	·827
5	·0038	·9962	·12	·88	·11	·89	·055	·945	·108	·892
4	·0024	·9976	·077	·923	·095	·905	·049	·951	·065	·935
3	·0014	·9986	·066	·934	·073	·927	·038	·962	·033	·967
2	·0006	·9994	·044	·956	·05	·95	·025	·975	·014	·986

It will be at once seen by the table that the last four scales are purely conventional, that is to say that the deprivation of light at the various angles in no way agrees with truth.

This exaggeration being admitted, the next thing is to consider how the best effect can be obtained in ground of all natures, whether generally steep or generally gradual, without the additional help of side lights or aerial perspective.

The contrasts then between the shades being the only means of obtaining the effect (which in other words means the appearance of relief), the scale that shews a due contrast between the shades at the successive angles is the best, and none fulfils this condition better than Lehman's, down to 5°.

In my scale, which is based on a similar progression, I have endeavoured to increase the contrast at the lower angles by a more rapid rate of diminution of the shade below 5°, giving a slight increase of proportion up to 10°, shewing a contrast of shade which can be obtained in no other way on ground of which the slopes do not much exceed that angle; and this may be said to be the case over nine-tenths of the surface of the globe.

The chief defect in Lehman's scale, is the complete obliteration of white at 45°, which, from its heaviness, fails to give the desired effect, an error which I have avoided, preferring a very thick stroke, which makes a very marked contrast with the angles below, even if the draughtsman fails to draw the hachures as close as they are shewn on the scale.

Next to compare Nos. 4 and 5 with reference to the way the shade is distributed. In both, the thickness of the hachure at 45°, is ten times that at the lowest angle, which in Lieut. Colonel Scott's is $1\frac{1}{4}$°.

The thickest and thinnest lines are ·017 to ·0017, and ·025 to ·0025 respectively.

The gradation followed by mine for the intermediate angles makes (vide table) hachures at between 10° to 5°, double the thickness of Lieut. Colonel Scott's.

In No. 4, the spaces are found by dividing an arithmetical progression of 1 to 10 into the cotangents of the angles of inclination, which follow an empyrical formula, these cotangents being calculated to the space in plan representing the assumed datum unit of level.

In No. 5 the same rule is followed down to 10°, but below that angle the number of spaces per unit remains constant.

Lieut. Colonel Scott founds the value of his shade by assuming a fixed proportion to the space representing the cotangent of the angle.

An investigation of the proportion of shade in the same space as given by my scale, shews an increase up to 10° of nearly double that shewn at 45°, and a rapid decrease to half that proportion at 2°.

The advantages I claim in favour of the scale I propose are:—

Advantages of No. 5 scale.

1st. As before described, a greater compass and contrast of shade, producing a better effect in drawings made with it, the contrast being also easily obtained, which is not the case in Lieut. Colonel Scott's scale at the angles below 4°, where the thinness of lines, though varying in the *scale*, can hardly be attained by ordinary draughtsmen, as may be seen in the drawings made at the Royal Engineer Establishment, for the Council of Military Education.

2nd. A greater facility of reading the drawings made with it: in the lower angles by the distance between the hachures, in the upper by their thickness, the scale shewing a rapid increase in both these respects.

3rd. A like facility in copying the scale with sufficient proximity to make the copy legible.

4th. The adherence to the same number of hachures between the contours in all angles below 10°, as most important to the draughtsman, who, though he may not mar the effect of his drawing by "dropping" and "taking up" hachures, as the contours converge and diverge when they are close and thick, would certainly spoil it in most cases, if obliged to do so, when they are open. Nor can this number of hachures at the lowest angles be considered insufficient to express the ground, as the space between them represents a difference of level of but one height on a scale of 6 in. to a mile.

5th. Lastly, the power of covering the paper at a more rapid rate than other scales in proportion to their minuteness, producing one-third fewer lines on any given area than Lieut. Colonel Scott's, when shading the manœuvring slopes. From this, considering the difficulties of adhering to it in other respects, I

estimate that it takes half as long again to make drawings by Lieut. Colonel Scott's scale as by mine on slopes below 10°.

Lieut. Colonel Scott has founded an hypothesis on his scale, that there is an artistic relation between the thickness of touches and the distance between them, and that every drawing which violates this supposed rule presents an inartistic appearance.

With due deference to him, I would state as the result of my experience of two years in instructing in the representation of ground to a scale of shade, in-doors and out, my belief that the individuality of the draughtsman lies in the thickness of his touch, and that no scale or artistic rule binds him in this respect, it being the only point in style in which it is found impossible to produce uniformity, while an equally good artistic effect is produced, and the distance between the hachures is preserved.

But as Lieut. Colonel Scott's original design implies the contrary idea, I must add that I have gathered it since from his own lips.

My own opinion is that artistic effect, as well as the "coup-d'œil" of the plan, depends on *correct drawing*, only to be attained by a course of instruction in accordance with the rules hereafter referred to, which are in conformity with natural laws; and it is to the rigid enforcement of these rules *alone*, that I ascribe the remarkable change that has taken place in the last year in the drawings produced at the Royal Military Academy.

Lieut. Colonel Scott would say (in proof of his hypothesis) that these drawings, though made to my scale of shade, are really more in accordance with his.

I am ready to acknowledge that a large proportion of them *are* made with finer hachures than those at the same distance apart in my scale. But the true reason for this is, that the A B C exercises with which a Cadet begins his course of drawing have not been altered to suit the scale of shade, for the simple reasons that no scale for general adoption has been as yet determined on, and the consequence is that each learner acquires a fine touch from these exercises, which are engraved from drawings by Major Petley, whose minuteness of touch may be seen by the example*. I venture to assert that if the alphabet was to scale, the after drawings would also coincide as near as can be expected in that respect.

On the ground which we work over about Woolwich, except in a few places, the slope never exceeds 7°, when, if shaded to a scale such as Lieut. Colonel Scott's, which shews very slight differences of thickness of stroke between 5° and 1°, the drawing would have no appearance of shade on it whatever.

Cadets' reconnoissances of Shooters' Hill, same as Plate I.

The examples I give, which include Shooters' Hill, the chief eminence in the country, prove my statement in the case where the touch has been fixed, and I may add, that if they had been made to Lieut. Colonel Scott's scale, where the strokes are closer at the lowest angles, the want of contrast would have been greater, even if the Cadets had been able to obtain the fineness of stroke at these angles.

It has been suggested by Lieut. Colonel Scott to diminish the thickness of the hachures on smaller scales, and the specimens* shewn of surveys, made by an officer at the Staff College, give examples of more than one scale being thus treated.

* Exhibited at the Meeting.

The drawings exhibited, 6 and 4 inches to one mile, sufficiently, it is believed, express the features, and I think down to 2 inches to one mile, as good an effect is obtained, and I therefore prefer the use of one scale only, premising that on any smaller scale the ground would be expressed by brush.

On the larger scales there can be no difficulty on this point, as the size of the undulations and accidents of the ground will be expressed in proportion.

With a special view to instructional purposes, and in order that each officer may be able, without hesitation, to carry out on service what he has learnt at the Academy, I have framed my scale as a contouring scale, adapted to all scales which are multiples of 60, so that after practising on small pieces of ground, on scales of 60, 30, 15, and 10 inches to the mile successively, he pursues an identical operation on the ordinary reconnoitring scales of 8, 6, 4, and 3 inches to one mile*, and he thus learns to estimate justly the size of the features which the scale he is working on admits of being shewn by contours. He soon understands that the mound, 50 feet high, which he represents on a scale of 60 inches to one mile, would depict a mountain 500 feet in height, if the scale of the same drawing was 6 instead of 60.

I may add, that the simplicity of the means also commends itself to those who understand the difficulties of the tyro. Furnished with a protractor, the sketcher possesses all that he requires to enable him to represent ground on any scale the multiple of 60.

On the flat side is his contouring scale, containing a scale of shade; on the bevelled side is the usual protracted arc and a plotting scale, by which, if he paces 32 inches, he can plot his distances.

By attaching a plumb line to the centre of his protracted arc, he has a clinometer with which he can obtain all inclinations to within a degree of the truth.

His memory is only burdened with one simple rule, which is, that at 60 inches to one mile, one pace equals one division on the plotting scale, and contours are drawn to one height.

The same data can be found for all other scales by dividing 60 by the number of inches to one mile, he proposes to work by. Thus, for instance: at 10 and 6 inches to 1 mile, each division on the plotting scale would equal 6 and 10 paces, and contours would be shewn at 6 and 10 heights, respectively.

2. *The use of Contours and scale of shade in rapid sketching.*

The use of a scale of shade in rapid reconnoissance requires further explanation than was given in my paper in Vol. XIV.

The questions that must arise are :—

1. Contours being absolutely necessary for the application of a scale of shade, can they be obtained in rapid work?

2. Having sketched contours with approximate accuracy, will time permit of the hachures being inserted over any portion of the work that has a perceptible inclination?

Where time is no object, doubtless contours can be obtained in the usual way, by levelling with a pocket level, as has been the practice at the Royal Military Academy and Royal Engineer Establishment, Chatham, an operation easily

* It is for instructional purposes alone that I advocate the use of large scales, and not, as Capt. James supposes, in military reconnoissances.

performed if the surveyor completed one superficial mile in 6 hours, inserting contours on 6 inches to 1 mile at 25 feet on gradual, and at 50 feet on steep ground. But that time is the most important condition in the execution of a sketch, none will deny; and this rate of progress, for contouring alone, would put that operation out of the question.

However, by the use of a contouring scale, divided to certain angles, with a vertical unit increasing and diminishing in proportion to the scale of the plan, approximate contours can be drawn as the surveyor progresses, without increasing materially the time of execution.

The process of contouring by means of the scale, described in Vol. XIV, is so simple that it is acquired by all the Cadets at Woolwich, *before they learn to survey.*

The success of every attempt to represent ground depends on their power of sketching contours; though the best eye for ground will do so fastest, all can accomplish it. In consequence, we can shew examination sketches, which for accuracy of execution in surveying and representing ground and rate of progress, will, I believe, bear comparison with results elsewhere obtained.

The examples* shown represent an area of about 24 square inches, on a scale of 12 inches to 1 mile, or one-sixth of a square mile, and were commenced and completed within five hours.

The shading is entirely based on a skeleton of contours, the Cadets having learnt no other method of working; and I may further remark that, within the present year, it is confidently expected that 80 to 90 per cent. will be able to come up to the same standard.

Contours being produced, the time that will be taken in filling in over them with hachures, on steep ground, may be estimated at about 9 square inches of paper per hour, if done with a pen, and about half as much again with the pencil. This estimate cannot be extended in proportion as the average inclination of ground is lowered, but that easy slopes can be covered much more quickly than steep, is not to be denied. For example, a fair draughtsman could cover 18 square inches of paper per hour, if the steepest slope was not more than 10°, and the features were bold.

I must confine this estimate entirely to draughtsmen who have learnt and acquired the rules laid down in page 141 of Vol. XIV. Corps Papers; for hill-shading, they are the "pons asinorum" of *all* but about 5 per cent. of learners; but once surmounted, they lead to the success of every one who commands the use of his fingers.

I may be thought to lay too great a stress on this point; but when I find that under the old style, without rules, no attempt was made at Woolwich to carry out in the field from the ground itself, the mode of representing learnt indoors, and compare it with the successful results of the present day, I hope I shall not be considered presumptuous, in supposing that the superiority of the new style over the old, is in proportion to those results.

I have exhibited examples of both styles, but have not space to shew, or time to describe, the history of the change which commenced about 2 years ago. As all present have probably some recollection of the standard reached in topographical drawing, during their career at the Royal Military Academy,

* Examination sketches exhibited at Meeting.

they will have an opportunity of judging for themselves by an inspection of the drawings of a *whole class*, which I exhibit.

It may be urged against the use of scales of shades, that although so often suggested, they have never been adopted in military reconnoissance. I shall venture to assert that the objections to them, which still exists in the minds of many, would be valid, had not all cause been done away with by the double victory obtained at the Royal Military Academy,

1st. In the introduction of the use of contours, drawn by a process which admits of the greatest rapidity,

2nd. In a correct *manner* of drawing, which enables all who care to master the rules, to shade the most intricate features with confidence.

3. *The combining of reconnoissances on the system laid down by General Jarry. Military topography in the British Army, during the Peninsular War.*

Sixty years ago, General Jarry, the instructor of men well-known as topographers in the Peninsular annals, viz., Pierrepoint, Mitchell, Freeth, Bainbrigge, Colleton, &c., said that reconnoissances should be mapped in less time than it would take the "Commander of the Army to ride over the country in which he intended to act."

Speaking of plans of positions, he says, that it is necessary that the relief of the ground should be represented, so that the advantages and faults of a position can be seen, the relative command distinctly read, and every object shown, that could impede or offer an obstacle to the movement of any nature of arm. In fact, so that the plan alone could be the field on which the Commander laid out his operations.

The chief merit (he says) of such plans, consist in the rapidity with which they are laid before the general. To accomplish a plan in 12 hours from the time it was ordered, he allows one person to every 3 square miles.

The "modus operandi" of each surveyor, is to make in the field an eye sketch of the country comprised in his portion, which is a sort of register, partly pictorial, partly written, upon which all that comes under his views is described, including a rough estimate of form and height of all elevations. Besides this, he lays down in a field book, a round of angles from each eminence, which, with all distances, are estimated roughly without actual measurement.

The data from these two means of registry are afterwards put together and drawn on a sheet, upon which are plotted any points which can be determined from published maps of the country.

I feel I have only to appeal to my hearers to be confirmed in my opinion,—that the putting together the work of a number of such operators, would take more time and trouble than the result would be worth.

That the information obtained would be wholly inadequate, if a knowledge of the command, inclinations, and form of the ground is a necessity, I feel assured.

The example of a sketch made in this manner at Wycombe* by some of these officers, under their instructor, will give some idea of the results.

A few remarks on the topographical staff accompanying Lord Wellington's army in the Peninsula may be interesting here, and will give some idea of how this system met the requirements of that day.

* Example shewn at Meeting.

Previous to 1810 there were not many well acquainted with the subject. Sir Arthur himself, in a letter to the Secretary of State in September, 1808, writes :—"In respect to your wish that I should go into the Asturias to examine the country, and form a judgment of its strength, I have to mention to you that I am not a 'draftsman,' and but a bad hand at description." The plan of the battle of Vimieira, now in the Quarter Master General's Office, could not have been made till after this, for although the position was occupied on the 19th, and the battle fought on the 21st, Sir Arthur writes on the 22nd of August, to the Duke of York, that he had not been able to obtain a plan of the ground. And although Napier says that he possessed an excellent map of the road from Lovrinham to Mafra, we find Sir Arthur during his advance on Lisbon complaining that there was no map of the country, and no person capable of giving information of a topographical nature.

In the subsequent operations in the advance on Oporto, previous to the battle of Talavera, the descriptive particulars furnished by Colonels Douglas and Bourke seem to have been mostly written. Nor does it appear that the report on the roads through the vale of Placentia and thence to Talavera, by Lieut. Colonel D'Urban, were accompanied by plans.

Although the site of the battle of Talavera was in the possession of the British for five days, Sir Arthur was unable to obtain a plan of the ground, and that forwarded by him to the Duke of Richmond a fortnight after, he says "is not very correct." Indeed, amongst the names of the officers of the Quarter Master General's Department at this time, very few are found of those who afterwards, with the Staff Corps of the Army, constructed the plans of portions of Portugal and Spain, still to be seen in the Quarter Master General's Office.

The original plan on which the lines of Torres Vedras were laid out was one made by Sir C. Stuart, in 1799. But its efficiency may be questioned by the fact of Lord Wellington's writing to Colonel Fletcher in October, 1809, that "an accurate plan of the ground is very desirable."

In the first half of 1810, while the British Army occupied the frontier, no less than the whole province of Beira, in Portugal, was surveyed on scales of 1in. to $1\frac{1}{2}$in. to 1 mile.

Thus Sir Arthur was placed in possession of maps of the whole country over which he moved in retreating to the lines of Torres Vedras, which was the scene of his subsequent successes in the following spring, when Massena was out-manœuvred and compelled to evacuate Portugal.

It is difficult to form an opinion as to whether the sketch of the Busaco ridge*, by Major Sturgeon, was drawn previous to the battle or not.

As Sir Arthur occupied the Convent of Busaco for seven days before the battle, as there was less time to make the survey after, and as the plan is dated September, 1810, I am inclined to think that on *this* occasion it was placed in the General's hands before the action was fought.

On the other hand, there can be no doubt that no good sketch of the ground, between the Duo Casas and Turones streams, was extant before the battle of Fuentes d'Onoro†. There was plenty of time to make it, for the country to the Agueda was occupied by the Allies for 20 days; but it is probable that the absence of the master mind in the south, relaxed the energies of the Staff.

* Original Plan of Busaco, exhibited. † Original sketch of Fuentes d'Onoro, exhibited.

Still five days remained after Sir Arthur's rejoining the Army, and if the drawings, productions of Colleton and Freeth, are the result of their exertions in that time, we cannot congratulate those officers on the successful carrying out of their instructor's ideas; but I am inclined to believe that the sketches were executed after the battle. The want of knowledge of the ground previous to the battle of Albuera, and consequent loss to the English, is a common instance quoted by military historians. Yet Marshal Beresford might have had it surveyed in the two entire days that clapsed between its adoption as the place to receive the enemy and the day of the battle; but Bainbrigge, who was probably the best topographer in the Army, was sketching on the Guadiana, 30 miles off.

In August and September, 1811, while Wellington was blockading Ciudad Rodrigo, and holding the line of the Agueda, that river from its sources, with all the country round the fortress, was sketched by Bainbrigge, Shanahan, Mitchell, and Bourke, but on a scale, (viz., 1 inch to 1 mile), too small to describe the positions.

From the 3rd to the 16th July, 1812, Lord Wellington occupied the line of the Duero, during which time, all the positions between that and the former, including St. Christoval, might have been sketched.

No sketches, however, are extant, and the plan of the battle of Salamanca*, by Pierrepoint, was made subsequently during the advance to Madrid. In the first advance to the Duero, no impediment from the enemy could have arisen to the Staff Officers making sketches of the country, as the advance guard was a day's march in front; but again we find no trace of them: and the miscarriage of Lord Wellington's plans, with the fact that Marmont overtook and outmarched him, proves a more intimate knowledge of the ground on the part of the latter.

Plates II and III. That Lord Wellington possessed a rough sketch of part of the position where the battle of Salamanca was fought, is proved by Colonel Bainbrigge's account in the "Aide Memoire," and the truthfulness of the sketch which he made is proved on comparing it with the survey by Sir Thomas Mitchell.

This example of what was achieved by one officer, viz., an area of 8 miles in two and a half hours, gives an idea of the skill of the individuals composing the Topographical Corps in the Peninsula. It being the only one of which a detailed account remains, is no proof that others were not as capable as its author; but from the plans I have seen, I should judge that, although Freeth and Mitchell could not be excelled in their several styles, neither of them had the same powers of giving a rough idea of ground with clearness.

In their retreat to Burgos, the French occupied successively six positions in the Pisuerga Valley, between the 11th and 17th of September. Four of these were roughly traced on half sheets of note paper†. Whether made in the presence of the French army by the British Staff Officers, or after their evacuation, and for what purpose they were intended, it is impossible to say. They could have been no assistance whatever to Lord Wellington in retiring over the same ground, or in occupying the position on the right of the Carrion on the 25th of October; and as a general map he had Lopez's Spanish one.

* Original survey of Salamanca exhibited.

† Original sketch on note paper, exhibited; consisting of a few lines.

The only sketch that I can find which comes up to General Jarry's ideas of what the plan of a position should be, was, however, made in this campaign.

Plate IV. It is by three officers, and on it is written that it was made in one day. Apparently the skeleton was enlarged from Lopez's provincial map. It describes the position of the army covering the siege of Burgos.

Three officers at least, then, being disposable for this service, it is very natural to feel surprised that no survey was made of the position of Monasterio, between Burgos and Briviesca, where Lord Wellington originally determined to meet Souham, the ground having been more than 20 days in the possession of the allies.

Time only allows of these very superficial remarks on the labours of officers who seem to have surpassed, individually, all their contemporaries, the officers of the Quarter Master General's Department and the Staff Corps having won for themselves, at that time, an European fame. My conclusions, on a careful examination of the result of their labours are,

That their general reconnoissance of large districts on a small scale are unequalled for beauty of execution, but of their accuracy I have no means of judging.

That the plans and reports on lines of march are fully equal to those made by Staff Officers in other armies.

But that their plans of positions on large scales, in most cases, were of little use at the time, and were not sufficiently accurate to be adopted as maps of record, from the fact that Sir T. Mitchell surveyed a second time those required for the atlas published by Mr. Wylde, after the war.

Their failure to come up to the standard of their instructor in the last respect, must be attributed to the want of a practical way of accurately combining sketches rapidly, and of uniformity in the mode of representing the features of the ground on large scales, as much as to the small number of officers actually available at any one point.

The Staff College. I would conclude these remarks on past experience by a reference to the results of the instructions at the Staff College, on this especial subject.

Hitherto, I understand, a scale of shade has not been made use of, but each officer applies in the field the instruction he has received in horizontal shading.

The best example is that which an officer has to make in a given number of hours, completing the drawing, in pencil, before leaving the ground. The one exhibited* is by an officer who was one of the highest of his term. The area is 11 square inches on a scale of 8 inches to one mile, or $\frac{1}{8}$ of a mile—time 5 hours. The ground has no detail of roads, hedges, &c.

I would again draw your attention to the examples shewn of work done in the same time by Cadets at Woolwich: we find that with equally intricate features, considerable detail, and the necessity of contouring, and applying a scale of shade, the same area is sketched on a larger scale.

I cannot positively state the percentage of the officers at the Staff College who approach this standard. In this respect they ought to excel the Royal Military

* Original sketch in pencil, exhibited.

Academy, as they are all tested in topographical drawing at their entrance, which is not the case at Woolwich. But even supposing greater results than I have stated are actually obtained, enough is shewn to prove the superiority of mechanical process in the most rapid sketch, and therefore the practicability of applying a scale of shade; and that not only without retarding, but even accelerating the process of representing the ground.

I am led to draw this comparison because it *has* been, and *will be* said that such a system may do very well for Topographical Engineers, but is not fit for Staff Officers, and with no wish to detract from the results of instruction at the Staff College, which equal anything produced on the same system.

Eye sketching, to produce these results, requires a combination in one man of artistic powers, and what is called "a good eye for country." How rarely we find the man! A great many possess the power of using a pencil to draw straight or curved lines; and at the same time have a tolerable conception of the form of ground. The scale of shade in the one case, and use of contours on the other, put the multitude on a par with the few.

I give a specimen* of a portion of a combined survey made by several officers at the Staff College. The officer who made it told me that he had the road, river, and one or two points laid down on his paper before commencing. It took him 18 hours to complete the area of 2½ square miles, and he has omitted many of the fences. The beauty of the drawing is undeniable.

It is evident that the fitting of this to the work done by the other officers depends on the data which were previously laid down. If there had been none given, it would have taken two hours more *at least* to have surveyed the margins so as to produce anything like coincidence.

I am inclined to think, therefore, that this system (like that of General Jarry's, in the Peninsula) would fail to produce combined sketches in a few hours, without *quite* admitting Colonel Nelson's statement in page 529, in the Aide Mémoire, that "it is in vain to expect accuracy or even tolerable general coincidence amongst the parts, when every man works quite independently, and without triangulation."

From want of time I am obliged to omit reference to the other examples which I had collected as illustrative of the science of military topography in the British Army since the Peninsular War.

4. *Additional remarks on the mode of combining the sketches of any number of persons for the purpose of obtaining within a given time the survey and representation of military positions of any extent. (Described in Paper VIII, Vol. XIV, Professional Papers).*

In no examples can I find that any other system has been followed than that of bounding the sketches by roads, rivers, or other defined lines, and obtaining coincidence in combining several, by accurately surveying along these margins.

In adopting meridional margin lines which shall be parallel to one another, the simplicity of the operation is so great that I am led to wonder why it has not been advocated as a means of combining sketches for military purposes, when so much has been written on the subject.

* Original Survey exhibited.

Mountainous countries, where the slopes *uniformly* exceed 20°, present the only difficulty to its use, and it is not on such ground that large bodies of troops are manœuvred.

Working along straight lines is a well known operation in penetrating wooded countries. The accuracy of the work depends on the accurate measurement and observation of but one line, instead of on that of many lines; and the only addition I would make to my description in Vol. XIV is that the surveyor ought to leave his line when crossing roads, and follow them out nearly to the margins.

A few remarks are, however, necessary on the representation of the ground in such a survey, which is carried on at the same time as the other work, and I must be excused repetition in doing so. The contours, which are shewn at various multiples of the average height of the eye from the ground, inversely in proportion to the scale, are marked along the initial lines as the surveyor proceeds. It is evident that he will always be either ascending or descending, except when the line coincides with a contour.

If each slope was uniform, and its vertical height exactly equalled any number of contours, the only inaccuracy that could arise would be from an error in observing the angle, and marking off the distance between contours from those given on the scale.

Such not being the case, it is necessary to exercise some judgment at the point where changes of inclination occur.

Plate V. Starting from A, at the level of "0 *contour*," the surveyor observes the angle of inclination, and paces to B, marking the foot of the ascent on his way. With these data, his scale of contours shows him that he has ascended $1\frac{1}{3}$ of a contour above A. He, therefore, marks on his line a point behind him at a distance (ascertained from his scale) due to $\frac{1}{3}$ of a contour at the angle of that part of the slope, which he figures No. 1. From B, he finds that No. 1 again cuts his line at C, the point where the inclination changes, by observing the angle and measuring from B a distance equal to the value of $\frac{1}{3}$ of a contour at the angle of inclination of B C. He then paces to C; and standing on No. 1 at that point, observes the angle of depression, and marks off in front of him a distance equal to 1 contour for that angle. On arriving at that point, he finds he is but a little above the watercourse, which by levelling proves to be 1 height; so that, standing at the watercourse, he can mark where 0 will come on the adverse ascent, whence he observes the angle of elevation; or if he could not see the top of the hill from 0, he would observe the angle from the watercourse, and when he had paced to E, mark the contours from 0, apportioning the spaces between 0, + 1, and + 2, so as to represent the actual angle of the slope; at E he would ascertain his height above + 2, in the same way as at B. From E to F and F to G, the same process would be followed. If F lay between + 1 and 0, and the slope from E to F was 3°, and from F to G was 5°, the distance between + 1 and 0 would be made as if that part of the slope was 4°, the point of change of inclination being shown by the hachures being closer below than above it.

The construction of the scale proposed by me is favourable to this operation of estimating portions of a contour, as the spaces for all the lower angles are divided into ten by the hachures.

As a rule, it is better to mark off the contours and number them along the line *in advance*, which a little practice in judging the length of a slope will enable the surveyor to do. Excepting to sketch-in the line of a contour, he will be then free to survey the details on each side of his line, until he reaches a point where the inclination changes, when he proceeds as before.

Errors in observing and estimating in ascents, are compensated for by like errors in descents; so that at the end of a long section line the accuracy of the relative level of each end thus obtained is very great. Looking at the example, it is plain that by following the same process the contours can be marked along any line crossing the initial one, a tolerably accurate basis being thus furnished upon which to sketch-in the contour lines.

Same as Pl. I. The drawings of a combined reconnoissance, done last year near Woolwich, exemplify the first attempt to instruct mere beginners in this process. As oral instruction was carried on all the time, the progress was of course slow, each step being individually explained to a party of five.

The ground, in many places, was intersected by streets and garden enclosures, and the detail throughout unusually close. Each party contoured independently of its neighbours on either hand, that is to say, no correspondence in the contours at the margins was sought for, but should this be requisite, the relative level of the starting points could be obtained by making a section of the base line in the way described for the initial lines. In either case, the scale of shade can be applied to produce a correspondence of the hachures.

The drawings themselves may not bear comparison with others in the room, but it must be recollected that they are the actual performance on the ground (inking in excepted) of mere beginners, and that improvement in the kind of paper used, and in the due expression of some of the details, will greatly improve the appearance of future productions.

5. *The requirements of a Commander in the field, and which system is best calculated to meet them.*

The topographical requirements of the commander in the field, whatever they may be, will be met, only so far as his combinations of battle comes under the heads of purely defensive, and defensive with the intention of attacking; to sketch a position occupied by your enemy, is, under ordinary circumstances, impossible, unless in company with a reconnoitring force large enough to convert the reconnoissance into a battle.

Battles that have been fought on the purely offensive system, have partly owed their success, either to a previous thorough acquaintance with the ground on the part of the commander, as at Leuthen, or to peculiar opportunities for reconnoitring the enemy, due to the form of the ground, as was Napoleon's case at Jena.

All writers agree that the chief information required by a commander respecting a position, is with reference to the lines of communication and retreat, tactical points, general form of the ground, natural and artificial aids to defence, the disposition and distribution of the defensive force in its three arms, and that the plan of the ground should alon express all that is necessary under these heads.

Colonel Bainbrigge's sketch being the best example about which I possess authentic information, I must ask you to compare it with the survey of the ground. You will find that the scale is not large enough to describe the tactical points, the aids to defence, or the capabilities of the ground for the three arms; that the roads are incompletely shewn, and that the general form of ground, though wonderfully accurate so far as it goes, considering the time given to sketching it, is most roughly expressed.

Indeed, under the circumstances described by Colonel Bainbrigge, I cannot imagine that the sketch could have been of much use to Lord Wellington. If his knowledge of the hills called the Arapiles, as tactical points, mentioned by Napier, was gained from this sketch, its apparent imperfection is readily accounted for.

The drawing omits altogether the scene of Pakenham's attack on the head of Marmont's advance, as well as the whole of the ground over which the enemy moved.

Colonel Bainbrigge follows throughout, if not improving on, the process described by his instructor, and yet we find that this system does not answer the acknowledged requirements of a military sketch, when time is an object; and if others had been able to multiply the performance of the same feat, the accuracy of the information would not have increased with the area represented.

Colonel Bainbrigge produced this sketch (he tells us) in pencil, in $2\frac{1}{2}$ hours, including the time he took to ride two miles to his ground, and the same returning; let us say two hours and ten minutes actually reconnoitring.

I shall, in a few words, describe the mode of proceeding about the same piece of work in the way I propose.

From the nature of the ground, I should decide to represent it on a scale of 4 inches to one mile, as sufficiently large to express the features.

Assembling my party at Santa Marta, and recognising the necessity of embracing the ground in rear of the position, I should start thence, measuring along a line bearing 190°. Having completed 750 paces, I should direct two of my party to commence work at that point, desiring them to measure along a line bearing 100°, sketching to a distance of 750 paces (represented by $1\frac{1}{2}$ in. on their paper) on each side of them, for a distance of $2\frac{1}{2}$ miles, and then to close to their right. At points successively 1,500 paces in advance, the same would be repeated, until I had eight parties, sixteen men in all, at work, sketching an area of $6 \times 2\frac{1}{2}$, or fifteen square miles, which is the smallest area that ought to be shewn on such a position.

The last party would commence work about two hours after leaving Santa Marta, completing their strip in $2\frac{1}{2}$ hours, by which time all the parties would have assembled at the opposite corner of the work to where they had begun. At this stage each strip would be in pencil, every object on the ground represented, and the drawing contoured to intervals of 75 feet, with intermediate "half-contours," or shaded to scale where necessary, and I should have to stitch the pieces together and ride $6\frac{1}{2}$ miles to Santa Marta, making $5\frac{1}{2}$ hours from the time of starting. But as I should prefer presenting the drawing in ink, I should allow $1\frac{1}{2}$ hours more for that operation, each party completing its own strip, giving about 15 inches of paper per man; an estimate of 7 hours, which I consider to be very liberal for the country in question.

As it took me one hour to copy Colonel Bainbrigge's sketch, I shall add 1 hour to his time for inking-in on double the scale, in all about $3\frac{1}{2}$ hours.

In comparing his drawing with my supposed one, I shall leave out the question of the numbers of the operators, because I should value one Colonel Bainbrigge as equal to sixteen men of the calibre necessary to follow my process, leaving the meeting to place what value they please on the services of the superintendent.

If Colonel Bainbrigge had doubled his area, he would have taken not less than 7 hours, also considering the increased distance he would have had to return.

My sketch would be accurate within its limits, and delineate every feature, natural and artificial, which the scale would shew. Its superiority to the other, in these respects, the meeting can estimate, Colonel Bainbrigge's sketch, and the survey of the ground being before them. Claiming a verdict in my favour, as to which system best meets the *acknowledged* requirements of a commander, I must now refer to what may be called the *unacknowledged* requirements of the commander, that is to say, a knowledge of the relative command, and angle of slope, of all parts of the ground.

That this would be legible on my plan, I am as sure of as that there is no idea of attempting to give such information on the other*.

But though beautiful in theory, it seems to me to be an interesting question how far this information might be made use of in practice. Therefore it is only in *that* sense that I call information of such a nature an *unacknowledged* requirement, for all will agree that the commander cannot know too much about his ground, seeing that (as Napier writes) a ditch 6 feet deep may be the means of turning the tide of battle.

I venture to suggest that the commander studying his plan, as the chess-player does his board, might profit by information of this nature, in the following way.

In placing bodies of troops in position for defence, or preparatory to using them for attack, a knowledge of relative command and inclination of slopes will enable him to do so in the most advantageous way, both for the service they have to perform and with regard to their safety from the enemy's fire while in a state of inaction.

If obliged to post troops on a slope exposed to an enemy's fire, the knowledge of the point of steepest inclination will enable the commander to select that as the safest point.

The choice of points of tactical importance must *now* be more governed by the minuter circumstances of slope and command than heretofore.

The selection of points where earthworks and obstacles may be placed will every day be of greater moment.

In tactical movements of troops, whether under fire or otherwise, a knowledge of the inclination of the ground is of more importance than generally seems to be allowed, so that the time which the movement is likely to occupy may be calculated.

When off roads, the rate of marching a mile on ground inclined at 3° of inclination, is sensibly decreased if the inclination is 6° or 7°.

* Nor is this a mere assumption, for even in the more careful drawings on which heights are relatively numbered, it is obvious that no dependence can be placed on them. None here could tell by the drawing shewn that the Busaco ridge is 250 feet above that opposed to it.

If troops are moving under fire, a knowledge of the ground is of still greater importance. Moving down a slope opposed to an enemy, is safety when the slope is steep, in comparison with when it is easy, the reasons for which are obvious. A knowledge of the ground swept by the enemy's artillery may suggest a favourable route for the advance of an attacking force; or may show the utter impossibility and recklessness of such an attempt. Cases have occurred where commanders have launched columns of attack into the jaws of death through ignorance of the ground and the effect of fire over easy slopes. One terrible instance of this kind occurred at the battle of Stone River, in the late American War.

Doubtless, instances of example may suggest themselves to the minds of officers present, either in favour or depreciation of the importance to a commander of knowledge of this kind.

It is quite true that the importance of the knowledge of the inclination of the ground in front of him will impress itself on the Divisional Commander, as well as on the officers of each arm of the service, and that they can obtain it for themselves in a moment. But although that knowledge *may* influence the accuracy of the fire, and decide the actual position of each man, or the best point for a breastwork, the General-in-Chief, holding the strings of the whole machine, *must* be in possession of the minutest information, should he require it.

Pictorial effect deceptive.

The means for producing what is called "pictorial effect" are *most* calculated to deceive the Commander, who expects to know more about the features of ground than their mere existence.

The example of ground near Wycombe, by the officers of the then Staff College, is to me more puzzling, perhaps, than to those who have not accustomed themselves to look at ground entirely with reference to its inclination. The same men sometimes gave the same shade to ground of double the angle of inclination when they reached the Peninsula. The deception, in one case or the other, practised unintentionally on the General, must have been considerable.

In comparing the portion of Colonel Eden's sketch of 1805, including Shooter's Hill, with that which I have exhibited, it appears to me that, although the Commander *might* never require to ascertain the exact angle of any slope, the comparatively truthful idea of ground, ruled alone by that condition, is infinitely preferable to an uncertain expression of the form of the ground, which being obtained without approximate contours, and shaded solely to produce effect, can in no way be depended on as a guide to the accessibility or otherwise of the ground.

In referring to this part of the subject, my chief difficulty has been the necessary brevity of my paper. Having occupied so much of the evening, I must conclude by asking the meeting to take an enlarged view of this subject, so important in military education, and having justly estimated what has been accomplished, to turn their attention especially to the consideration of the probable requirements of a commander in the field, and the best way of meeting them.

C. E. W.

DESCRIPTION OF PLATES TO PAPER II.

No. I.—Is the fac-simile of a survey made in six strips, on the system described in Paper VIII, Vol. XIV; the contours upon which the shading is based are obliterated by it, but they could be shewn by a coloured line.

No. II.—Sketch of the position covering Salamanca, on the left bank of the Tormes, made for Lord Wellington by Lieut. Bainbrigge, during the siege of the Salamanca Forts.

No. III.—Survey of the same ground made by Lieut. Mitchell after the war.

No. IV.—Fac-simile of an original sketch made in one day by three officers during the Peninsular War.

No. V.—Plan and section illustrative of the mode of contouring while surveying one of the strips in Plate I.

N.B.—This drawing is reduced by photography from a diagram exhibited at the Meeting; the letter-press, which was printed before the discussion, referred to the diagram, consequently the contours are not at intervals adapted to the scale of the reduced drawing.

No. VI.—Plate of conventional signs, &c., in military drawing, sanctioned by authority for general use in the British Army.

POSTSCRIPT TO PAPER II.

Since the paper on Military Sketching was printed, I have seen some original sketches and documents in the possession of Major General Bainbrigge, R.E. (made by his father), of the country along the line of the Duero, east from Valladolid, and along the Pisuerga and Arlanzon Rivers to Burgos. These sketches are fully equal to others made by that Officer on a scale of 1 inch to 1 mile, and are put together in one plan, on a scale of 4 miles to 1 inch. Their existence shows that I was mistaken in supposing Lord Wellington (during his retreat on Valladolid) had in his possession only the sketches consisting of a few lines, now in the Quarter-Master General's office.

With reference to paragraph 2, page 38, I am inclined to think that Plate IV *is* the actual position in *front* of Monasterio, which Lord Wellington proposed to occupy against Souham, and that I was misled by the historical description given of its whereabouts.

PAPER III.

MILITARY SKETCHING*.

By CAPT. E. R. JAMES, R.E.

In the following remarks I propose to treat only of military sketching, by which I mean that which is needed in an enemy's country, if not actually in the enemy's presence, which is performed by pacing, and with only such instruments and appliances as can be carried on the person, and by which it is desired to produce certain results with a moderate degree of accuracy in the least possible time.

I must be understood to advocate the horizontal system of shading, and I believe I shall go so far without difference of opinion, and I will commence, as Lieut. Colonel Scott did in his paper, with the supposition that the ordinary work of the surveyor is finished, and we have only to do with the ground. This supposition is convenient for us, but in the practice of military sketching, a skilled hand would perform every operation at once, and would avoid visiting any part of the ground a second time. But as the consideration of the delineation of the "details" (as the villages, roads, streams, &c., are generally called) would only confuse us, we will suppose they are complete, and that we have only to do with the "features."

So many different systems have been advocated, that I must premise at once that I should not consider that to be a good one which was not based on the following conditions:—

1. The light falls, as in Lehman's system, in parallel vertical rays, and not from the north-west corner of the plan at an angle of 45° to its plane, as some writers have assumed.
2. A scale of shade adapted to inclinations without reference to comparative altitude is made use of. The drawing (Pl. II, Figs. 1, 2, 3, and 4) shewing representations of a regular truncated cone by various means, mechanical and artistic, is intended to shew what a false effect of relief, and light and shade, is produced by any but vertical light, or by shading by any other method than inclination.
3. The sketching is based on contour lines. It will be explained later that this does not entail the actual contouring of the ground as a preliminary to the sketching.

* A Paper read at a Meeting at the War Office, May 12th, 1866.

4. The process of sketching must be strictly mechanical, and the sketcher need not necessarily be an artist.

5. The sketching must be capable of being read by the General in command, or by any one else, according to fixed rules. In fact it must be a conventional projection of the features of the ground, as much as the roads and streams are a projection of the "details."

The scale of shade made use of must necessarily be conventional, but we may assume certain axioms in its preparation, the truth of which will be apparent to a close observer of nature. They are as follows:—

A. Slopes above 45° never occur in unbroken ground in nature, but only on the sides of protruding masses of rock, cliffs, landslips, artificial cuttings, embankments, quarries, &c. In the ground at Aldershot, represented in Plate III, the maximum slope is 30°, but only in a few places. The steepest slope *in general* does not exceed 20°. Most of the officers present will know this ground, and probably have thought there were inclinations of 45° upon it.

B. The horizontal system is not adapted for the representation of slopes steeper than 45°, and such slopes ought invariably to be shewn by vertical touches. (Pl. I, Figs. 1, 2, and 3).

C. By a natural law, the average rise of ground increases as the ground increases in elevation. By this law, mountains (although the ground may be represented by a scale of shade having no reference to comparative altitude) will be distinguished by long steep slopes, and consequently masses of dark shade.

D. Continuous steep slopes never follow the same inclination from top to bottom. A section of steep ground is usually some modification of what artists term the line of beauty, that is to say the ground at first falls easily, then rapidly, and lastly easily again, thus . Any scale of shade must of necessity give the sketch of such a feature a rounded appearance on the plan, with due prominence to the steeper ground where prominence is needed, and thus a representation of a succession of such features conveys in the aggregate the due effect of relief to the eye. The light is admitted on the tops of the hills and in the valleys with a proper gradation of tone between the light and the shade caused by the gradual changes of inclination of the ground. The section of a deep ravine is, I may say, never in the form of a V, but rather in that of a very open U; neither is a ravine ever in the shape of a trough, but rather in that of an inclined pipe, opening with easier slopes as the thalweg descends. The steepness of the thalweg varies with the steepness of the sides of the ravine. (Fig. 4).

E. Hard lines, separating slopes of different inclinations, rarely exist in unbroken ground in nature, but there is usually a gradual change from slope to slope. Pl. I, Figs. 5 and 6, represent natural sections of ground; Figs. 7 and 8 represent sections of ground which rarely exist in any modification in nature.

The rendering of the ground by a scale of shade, in obedience to these axioms, ensures a sufficient quantity of light being toned into a sketch without any sacrifice of truth, while a due effect of relief is *ensured by purely mechanical means.*

Referring again to the representations of the regular truncated cone, I should point out that such a form of ground is unnatural, and therefore the want of pictorial effect in the first figure is no proof that a sketch by scale of shade would be wanting in pictorial effect.

Anticipating objections to my theories regarding pictorial effect, I, some time ago, prepared Scale 9 (see Pl. IV) as a means of agreement between the mechanical and artistic schools; but I do not regard the effect I can produce by such a scale as so good as that produced by a scale of shade adapted to altitude only, but constructed with a view to pictorial effect, as Scale 10. (See Pl. IV.)

The greatest opponents of a scale of shade cannot deny that whatever the pictorial effect produced may be, the advantage of getting similarity of workmanship (when a plan is produced by a section of men working simultaneously at different points) cannot be overlooked.

But the effect must be dependent on the particular scale of shade chosen, and, as I shall endeavour to explain, the choice must be affected by a consideration of the scale of the plan and the extent of country to be sketched.

I would rather establish general rules for the construction of scales of shade, than restrict the sketcher to any one scale in particular.

A military sketch may be made hastily before or near the enemy, in which case 10 square miles would be its probable limit, or it may include the unexplored parts of a colony, and be several hundreds of miles in extent. In the former case the relief need only be considered with reference to the highest and lowest points (200 or 300 feet at most, probably), but in the latter the relief would extend from the summits of high mountains to the level of the sea (perhaps 10,000 feet); in the former case the plan scale would be a large one, and in the latter a small one.

In the former case, the work would be hastily executed, in the latter, with a degree of care; in the former case, the small relief would not leave room for pictorial effect, while in the latter this would be essential to enable the student of the map to form a speedy conception of the general form, rather than the details of the features of the country. One scale of shade would obviously not be applicable to both.

And here I may be allowed to raise an objection to a principle laid down, both by Captain Webber and Lieut. Colonel Scott, that military sketches will ever be made on such scales as 60 inches to the mile, or even $\frac{1}{2500}$ (25 inches to the mile nearly). These scales are very useful for small, carefully-made, special, contoured-surveys, where huts, lines, redoubts, watering places, batteries, &c., may have to be established; but for purposes of military reconnoissance and tactical operations, I submit that no larger scale is convenient, or is ever likely to be made use of, in the field, than $\frac{1}{10000}$. Maps, for such purposes will vary from this scale to 1 inch to the mile. 6 inches to the mile and $\frac{1}{10000}$ are so nearly alike that one scale of shade will answer for both*.

* In Laisné's "Aide-Mémoire," page 74, a very good table, shewing the scales proper to be adopted for various plans, is given.

The scale of shade should be determined before commencing a sketch, and being drawn in a similar manner to the scales in illustration of this paper, it should accompany the report sent with the plan to the commanding officer. It should be as much an essential as the plan-scale and the meridian.

Lehman, in his system, commences as I do, by supposing the light to fall vertically, but the first conclusion he draws is such a false one, that he makes us suppose he meant to say the light should fall at an angle of 45° to the horizon, for he assumes that because a slope of 45° is the steepest in nature, it is properly represented by absolute *black*.

What does he do, I would ask, with those features I propose to shew by vertical strokes? He must ignore them; but what would a General say if he were to come suddenly on a precipice on ground which, from his plan, he thought accessible for one or more arm of the service. A slope of 45° is a complete obstacle to the advance of troops, and it is not, therefore, necessary for us to shew much distinction between various slopes steeper than 45°. These I propose to shew all alike with a vertical touch, with more or less light thrown in, but *not* in obedience to a rule; the guess-work of our old sketching will, to this extent, do no harm. And, again, if the slope of 45° were represented by black, what use would the plan be to the General who needs information regarding the details, and what labour the penning-in would be to the draftsman? We may properly assume that the projection of a vertical plane being a line, *it* must be represented by "all black;" the projection of a horizontal plane being an unbounded space by "all light," and (following this reasoning) that the shade on any slope is to the light as the perpendicular to the base of a right-angled triangle, when the angle opposite to the perpendicular is equal to the angle of inclination. This would be in the proportion of the sine to the cosine, and at 45° we should have half-shade and half-light; as the shade decreases from 45° to 0°, the light increases.

Thus, on any system of scale of shade, we have two mathematical series to determine, an increasing one for the lights and a decreasing one for the shades; the first term for each series being the thicknesses of the hachure and lighted space at 45°. Supposing the latter point to be settled for the moment by fixing $\frac{1}{48}$ inch for the hachure, the sine and cosine series gives us Scale No. 1 (see Pl. IV), which nearly corresponds to the scale we might deduce from old sketches as they have been executed for years past. In my opinion no one except an artist or at any rate a very practised hand) could with it produce the pictorial effect it is capable of producing, not to mention the extreme labour of executing a sketch by it on the manœuvring slopes. But we may lighten this labour by exaggerating the light at the lower angles, and substituting the tangent and cotangent for the sine and cosine. We thus obtain Scales Nos. 2 and 3, really good and truthful scales, producing an excellent, though a different, pictorial effect. In the first of these scales the maximum stroke is $\frac{1}{48}$ of an inch, and in the second $\frac{1}{60}$ of an inch. The difficulty of carrying the progressive values of the terms in the memory is a great objection to these scales, but in some respects I shall nearly adhere to them in the more easily constructed but almost *unpictorial* scales which I shall propose. But here let me express my conviction that *pictorial effect* is a very secondary consideration in small military sketches. In matters of taste there is no law, and who shall decide what effect *is* pictorial?

We want accuracy of representation, with rapidity, and if by changing our effect we can obtain these, I do not fear but that we shall in time come to regard our new sketches as being equally useful, if not equally pictorial, with our old ones. Do we not similarly regard the changes of costume which fashion imposes on us year by year?

But in giving expression to this heresy, I must support it by another, in which I think the advocates of shading by scale will agree with me; that no artist, merely working by his ideas of taste, can produce anything in pictorial effect to compare with our productions by rule, when our scale of shade has been expressly constructed with *a view to pictorial effect.* The arbitrary Scale No. 10 is so constructed. It is adapted to inclinations only, but is deduced from old sketches of the best description. I have seen a great extent of work done with it with very perfect results, but with very great labour.

To resume. The decreasing series for the shade in the tangent and cotangent scales follows an arithmetic progression nearly, while the increasing series for the light follows a series with a progressively larger difference between the terms. Therefore assuming the decrease in the amount of shade, or, in other words, in the breadths of the hachures, to follow a regular arithmetic series by ninths, at intervals of 5°, as Lehman does, and the breadth of the lighted spaces to increase in any progressive series we may for convenience fix on, I shall be able to assume data for making a scale of shade for any plan. An examination of Scales Nos. 2 and 3, in which the lights increase by ninths, in the same manner as the hachures decrease, will shew that an *arithmetic* series is *not* fitted for the increasing one. In the former of these scales the maximum stroke $= \frac{1}{45}$, and in the latter $\frac{1}{60}$. In the construction of the scale of shade, I hold (in opposition, I believe, to Capt. Webber) that the smaller the plan-scale is, the finer must be the hachure at all inclinations, and the greater must be the proportion of the light to the shade. On a scale of 6 inches to the mile, an inclination of 3° can be indicated, but on a scale of 1 inch to the mile, the expression of any less inclination than 10° only confuses the entire sketch.

The minimum inclination capable of being shewn on a plan will give us a starting point from which we can arrive at the proper thickness of hachure, and the breadth of the lighted space at 45°. The breadth of hachure should diminish from 45°, in arithmetic progression, at intervals of 5°, as I have explained; this, therefore, becomes a fixed quantity for each inclination, but the breadth of the lighted space must increase as the inclination decreases.

I will explain the construction of the scales I would propose for 6-inch and other scales, 8, 8*a*, 8*b*. (See Pl. IV).

Different writers have assumed various thicknesses for the maximum and minimum strokes on the 6-inch scale; the maximum of Lieut. Colonel Scott (Scale 6) being $\frac{1}{60}$ of an inch, and the minimum $\frac{1}{600}$. He also gives $1\frac{1}{4}°$ as the least inclination which can be expressed, and assumes that the "vertical unit" should at this slope be expressed by ten strokes of the minimum thickness. Now as this "vertical unit" on his system differs for various scales, and at various inclinations, it appears to me that its introduction is only an element of confusion. Neither can I agree with Lieut. Colonel Scott, that so small an inclination as $1\frac{1}{4}°$ can be appreciated on a plan 6 inches to the mile; or that, if it could be appreciated, any benefit would accrue to the military service by representing

it. And I differ from him again when he fixes $\frac{1}{500}$ of an inch as the breadth of a stroke to be drawn with a free pen. Captain Webber (Scale 7) fixes $\frac{1}{40}$ inch as the maximum stroke (rather too thick I think) and $\frac{1}{400}$ as the minimum. Practically, the minimum will be alike for all scales, and will depend on the fineness of the pen used by the sketcher, and the steadiness of his hand. For rough work on service, I prefer to fix it at $\frac{1}{400}$, or (for convenience) $\frac{1}{405}$, at 5° and under, and, considering this as the first term of nine in an arithmetic progression, the maximum stroke will be $\frac{1}{45}$ at 45°, though, practically, I would give the maximum stroke a range between $\frac{1}{45}$ and $\frac{1}{50}$; but calling it $\frac{1}{45}$, an inch divided into 45 parts, and these parts, shaded and left in light alternately, will therefore give us the darkest degree of our scale of shade.

These series, for the progressive breadths of the strokes and lighted spaces, will satisfy the conditions I have established, and at the same time give us a very convenient rule.

Series to Show the Successive Breadths of the Hachures and Lighted Spaces at Different Inclinations.

(For a Scale of Six Inches to the Mile).

HACHURES.

	in.		in.
45°	$\frac{1}{45}$th	...... or	$\frac{9}{405}$
40°	$\frac{1}{45} \times \frac{8}{9}$	=	$\frac{8}{405}$
35°	$\frac{1}{45} \times \frac{7}{9}$	=	$\frac{7}{405}$
30°	$\frac{1}{45} \times \frac{6}{9}$	=	$\frac{6}{405}$
25°	$\frac{1}{45} \times \frac{5}{9}$	=	$\frac{5}{405}$
20°	$\frac{1}{45} \times \frac{4}{9}$	=	$\frac{4}{405}$
15°	$\frac{1}{45} \times \frac{3}{9}$	=	$\frac{3}{405}$
10°	$\frac{1}{45} \times \frac{2}{9}$	=	$\frac{2}{405}$
5°	$\frac{1}{45} \times \frac{1}{9}$	=	$\frac{1}{405}$

LIGHTED SPACES.

		in.		in.
45°	$\frac{1}{45}$th, or	$\frac{2}{45}$	—	$\frac{9}{405}$
40°	....	$\frac{2}{40}$	—	$\frac{8}{405}$
35°	....	$\frac{2}{35}$	—	$\frac{7}{405}$
30°	....	$\frac{2}{30}$	—	$\frac{6}{405}$
25°	....	$\frac{2}{25}$	—	$\frac{5}{405}$
20°	....	$\frac{2}{20}$	—	$\frac{4}{405}$
15°	....	$\frac{2}{15}$	—	$\frac{3}{405}$
10°	....	$\frac{2}{10}$	—	$\frac{2}{405}$
5°	....	$\frac{2}{5}$	—	$\frac{1}{405}$

The progressive nature of the differences in the series for the lights is clear at a glance, and both series can be easily carried in the memory. The rule for the construction of the scale is as follows: (Scale 8, 6 inches to the mile).

One inch being divided by the number of degrees in the angle of inclination, every two divisions make up the total breadth of one hachure and one lighted space; this fixes the number of strokes, the thickness of hachures at each angle being already fixed.

This scale of shade has advantages over all others I have seen, in that,

1. It is constructed by an easily remembered rule of thumb.
2. Being almost similar to the tangent and cotangent scale, it is conventionally true.

3. The field-work of the sketch can be done very rapidly by its use.
4. The labour of penning the sketch is small, and the deeper shades do not obliterate the details.
5. The principle of construction is applicable to other plan-scales, by simply altering the unit of one inch (the distance to be divided by the number of degrees in the angle of inclination) to suit the scale (Scales 8*a* and 8*b*).
6. And lastly, the plan is read with facility by the following rule:— "Lay the edge of any divided scale of inches at right angles to the hachures, and multiply the number of hachures in an inch by 2 for the angle of inclination."

Pictorial effect is, in Scale 8, entirely sacrificed, but by the substitution of Scale 8*a* or 8*b*, a good deal of pictorial effect can be obtained, or by the use of the entirely arbitrary Scale No. 10 (when the survey is extensive and there is time) artistic results can be produced. But the reading by the rule given for Scale 8 can only be accomplished with precision when there has been time to execute the sketch with a little care. In very hasty work indeed it would only be necessary for the sketcher, having found his inclination upon the ground, to copy from the established scale of shade by eye, and the General would reverse this process in reading the plan by comparing the sketching with the scale of shade accompanying the plan. But it must be noted that two or three strokes, more or less, would not affect the angle of inclination to any considerable extent in steep ground, and in ground fitted for manœuvres the necessary number of strokes in the inch could be judged by the sketcher with sufficient accuracy without measurement of an inch by the edge of his plotting scale. By a little practice the degrees of the scale of shade become perfectly familiar to the sketcher, and he is able to strike the proper thickness of light and shade without reference to the established scale. And as the penning of the sketch must be done at his quarters, all that he need do on the ground is to note the inclinations, the salient points of certain contours, the directions of the hachures, and such irregularities of the surface or accidental features as are thought of consequence. He, in fact, need only establish data on the ground for completing his sketch rapidly at his quarters, and in this way a maximum of work can be done in a minimum of time. Capt. Webber advocates finishing a sketch in pencil on the ground, but I think time is lost and nothing gained by it. The central portion of the sketch of ground at Aldershot (Pl. III) is represented by Scale 8, and the eastern portion by the pictorial Scale 10, with, perhaps, ten times the labour.

The degree of inclination would not, however, be by any means the only consideration in judging of the power to execute manœuvres. In Lehman's table, the manœuvring slopes cease at 15°, but he considers it possible for infantry and cavalry to advance with more or less difficulty along slopes of even 30°, and that light infantry in open order may sometimes ascend slopes of 45°. The latter feat was proved practicable by the Zouaves at Alma, and the English troops, in the same battle, advanced in order along moderately steep ground. But it will be remembered how greatly the *roughness* of the nearly level ground passed over by the English troops in the early part of the battle disarranged their formation. It is therefore of the roughness of ground I would speak.

Ground may be covered with wood; it may be marshy; it may be arable or pasture; the surface may be rocky, uneven, or boggy; or the enemy may have covered it with artificial obstacles—abattis, troux-de-loups, &c. The presence of the latter is usually unexpected by the attacking force, and woods and marshes have always been well shewn conventionally on plans. I need not, therefore, consider how a sketcher would indicate these; and rocks would generally be marked by the vertical touches I spoke of at the commencement of the paper. But as regards unevenness of surface, the general inclination of a slope, A B, (shewn in Pl. I, fig. 9) may be, say 10°, but the surface may be broken up into minor irregularities yard by yard, presenting here a crevice, and there a little pitch of even 20°. Artillery and cavalry could only advance along such a slope with difficulty, and it should be distinguished from a smooth slope of 10° by breaking the hachures into short rough lengths, interspersed with minute vertical touches (fig. 10). A smooth practicable slope, on the contrary, should be marked by long straight or evenly curved hachures (fig. 11), and wet or boggy ground, impassable for heavy carriages and difficult for cavalry and infantry, should be represented, whether on a slope or not, by short blue lines running east and west, put in with a brush (fig. 12). As the knowledge of a road may often decide the fate of an action, by rendering the passage of artillery possible, the sketcher should be careful to omit the hachures on the roads in steep ground, so that the eye may be drawn to the latter at once (fig. 1).

The next point to be considered is how to judge inclinations in the field, for unless we can do this any scale of shade is useless. It has been proposed continually that it should be done by means of contour lines, and the inclinations at which ground must lie when contours of a fixed vertical interval are at certain horizontal intervals.

Pl. II, fig. 5, represents a boxwood scale, which was introduced to my notice by Captain H. H. Jones, Royal Engineers, for the purpose of measuring the inclination of the ground in this manner, on a 6-inch-to-the-mile plan. It is arranged for vertical intervals of 100, 200, 250, and 500 feet, and being laid at right angles to the direction of the contours, and its zero placed on the intersection of its edges with one contour, the inclination of the ground is read off at its intersection with the next. These scales may be made for a shilling each of box-wood, or they may be made of stiff cardboard, to suit any plan and any vertical intervals.

But the use of such a scale implies the existence of a contoured survey to work upon, and I submit that, for military purposes, a plan closely contoured, ever so roughly, is infinitely superior to a sketch of ground with hachures only. When there is time to make a contoured sketch, let it be done by all means, but do not add hachures and confuse the more valuable contours.

Contours at vertical intervals equal to the distance from the foot to the eye of the sketcher are put in with comparative ease, and a plan contoured at such short intervals is preferable to a sketch with hachures. The western part of the ground at Aldershot (Pl. III) is represented in this manner, and such a plan is more rapidly made, and is more useful when made, than the pictorial sketch (by Scale 10) on the eastern side of the same ground.

But the principles involved in surveying these contours may be made available in sketching ground, without the labour of completing the contours themselves, as I propose to show.

The height of the eye varies in different men from 60 inches to 65 inches, but 62 inches being about the average height, I will use this distance in my illustration. In practice each sketcher would use the height of his own eye.

The following is a table calculated once for all by plane trigonometry, giving surface and plan measurements in paces (25 to the chain), taken in a direction at right angles to adjacent contours, whose vertical interval is 62 inches, the surface of the ground being unvarying in inclination between each pair of contours.

TABLE FOR CONTOURS AT 62 IN. VERTICAL INTERVALS, FOR BACK OF PRISMATIC COMPASS.

Inclination.	Plan.		Surface.	
	Links.	Paces 2,000 per mile.	Links.	Paces. 2,000 per mile.
$2\frac{1}{2}°$	178	44·5	178	44·5
5°	89	22·25	90	22·5
$7\frac{1}{2}°$	59	14·75	60	15
10°	44	11	45	11·25
$12\frac{1}{2}°$	35	8·75	36	9
15°	28	7	29	7·25
$17\frac{1}{2}°$	25	6·25	26	6·5
20°	21	5·25	23	5·75
25°	17	4·25	18·50	4·62
30°	13·5	3·25	15·64	3·91
35°	11	2·75	13·63	3·40
40°	9	2·25	11·89	2·97
45°	7·82	1·95	11·06	2·76

This distance of pace can be easily acquired by any man by measuring a distance of 4 chains on a level place, and pacing it until he can rely upon the number of steps he takes being one hundred. Two thousand of such paces go to a mile, and they can be plotted from a scale of miles and paces, or from one of chains and links, the latter being obtained on the ground by simply multiplying the paces by 4. The distance between the base and the hypothenuse of a right-angled triangle, whose perpendicular is 62 inches, is so small when the angle of inclination does not range above 20°, that for the 6-inch or smaller scales the surface-distance may be taken practically as the plan-distance up to that inclination. Above 20° it is impossible to pace with the same length of pace or with regularity, and it is therefore recommended that the sketcher should move obliquely from contour to contour at high inclinations, and thus avoid the necessity of pacing along a steeper slope than 20°. At the very steepest inclination the direct measurement can be made with a rod, such as a common hedge stick, notched in links.

I may here remark that the advantage of making the surveying pace always equal to the military marching pace of 30 inches, is, at most, but a theoretical one, for troops are taught paces of four lengths—quick, short, step-out, and

double—and surely can acquire any other as easily as these were acquired. If they can master surveying, they can master this smaller difficulty. Captain Webber has proposed that there should be a constant proportion of 2 to 1 between the height of the eye and the length of pace—the former to be 64 in. and the latter 32 invariably; that is to say the latter is to be 2 inches more than the military quick pace, and the former 2 inches above the average height of the eye of a man. The tendency to return to natural rules could not be overcome, and thus errors must arise from the proportion between the two measurements not being strictly kept. My pace is half an inch shorter than Capt. Webber's, and I find it one I fall into naturally when walking along a level road at the rate of about three miles an hour, but, nevertheless, it may not suit everyone, and I do not therefore wish to prevent anyone from adopting a pace which may suit him better. I only point out the advantages it clearly has, and recommend a trial of it. The height of the eye by my system varies naturally, and the vertical and horizontal measurements need not bear any fixed proportion.

Captain Webber has recommended the use of the edge of the protractor as a level or clinometer, and he informs us that his method gives surprisingly accurate results, but I must confess to being sceptical on this head.

Capt. Baillie, in a lecture given at the Royal United Service Institution, some years ago (see Vol. I of the Journal of the R.U.S.I.) recommended, for field sketching, a very ingenious, but a thoroughly impracticable plan of levelling with a pocket sextant, a jar of mercury and a tripod stand, and I should very much like to have seen him make use of it before an enemy. I think I have heard as many impracticable suggestions on this head, as were given to rid us of the cattle plague, or to launch the "Northumberland," so I will beg to recommend a plan myself, which, to me, seems very simple. I use a modification of the eye level, described at page 113, of Heather's Treatise on Mathematical Instruments, which I can construct in five minutes, at the cost of a penny—the material being always at hand on active service in the military artificers' shops. It is simply a right-angled isosceles triangle of bright tin plate (Pl. II, fig. 6) pierced near the right angle, and a string with a bullet at the end attached to it. Being held at arms-length, the string and plummet enable me to place the sides in a vertical plane, and the hypotheneuse in a horizontal line; I then bring the vertical plane at right angles to my line of sight, by making the horizontal line bisect the reflection of *both* my eyes; then, marking the apparent intersection of the horizontal line with the ground in front of me, I obtain a point, 62 inches higher than my position, on which I pace to find the next contour, or a surface-distance which enables me, by reference to my table, (which I paste or engrave on the back of my prismatic compass) to find the inclination of the ground.

The tin triangle may be made available as a clinometer or level, and used according to Captain Webber's system, although I conceive the method I have proposed will render the use of such an instrument unnecessary, for it must be remembered that we are supposed to be inserting the details with the features, and cannot advance too rapidly. In using *any* clinometer, error is apt to arise from the want of an horizon, for we naturally, in looking up-hill, observe too small an angle, and down-hill too large an angle. This I correct in the follow-

ing manner :—I paste a piece of white paper, or paint a white line round the measuring rod, at the height of the eye. The rod being stuck in the ground, or held by an orderly, (which we may suppose would be the case on active service, a lancer could use his lance without dismounting,) may be made to act as a levelling staff in running a contour, or to assist in directing the edge of the clinometer parallel to the ground in observing an inclination. In *distant* observations for levelling or inclination, the use of the rod is unnecessary.

Much labour may be spared by marking the initial points and directions of the contours along the watersheds and thalwegs. If this be done carefully the intermediate portions can be sketched rapidly and with tolerable accuracy by eye. On even slopes, every fourth or fifth contour only need be initialled, the rest being interpolated by eye.

I have wondered that neither Lieutenant Colonel Scott nor Captain Webber, in their papers, have recommended the use of the pocket aneroid barometer for fixing heights approximately. Having sketched or contoured the ground on the principles I have laid down, the several slopes would be represented accurately enough to enable a general to judge whether they would be practicable for troops of any arm of the service, but scarcely accurately enough for him to be certain of the relative relief or command of points within the range of artillery practice.

I therefore recommend the following plan :—A fall of an inch of the barometer represents a rise of 1000 feet very nearly, when the total relief does not exceed that quantity. The pocket aneroid is about the size of an English hunting watch; its arc is usually divided into tenths, representing 100 feet each. I would attach a vernier scale to the rim, to slip round with a slight pressure of the finger, to read hundredths or to 10 feet. The sketcher reads his barometer on leaving camp, and records observations during the day at principal points, noting the time at each. If there be no considerable change in the direction or force of the wind, or in the temperature of the air, he will find that the hand of the barometer has reverted nearly to its original place when he returns to camp and reads it a second time. Half the difference between the morning and afternoon readings in camp must be equated among all the readings in proportion to the times of the observations; and each corrected reading with a cypher in the third place of decimals being assumed to be a whole number, the difference between any pair of readings will be approximately the vertical interval in feet. For instance :—

The lower reading corrected being ...... 30·010
The upper reading corrected being ...... 29·860

The difference of level is .... 150 feet, and this may be assumed to be within 10 feet, or not exceeding 5 per cent., but in excess, of the true difference. When the difference of level is greater, the proportionate error is less.

Means for the heights of principal points on the sketch could be obtained from observations on different days, and these serve to prove or correct the minor points. It adds little to the trouble of sketching to carry an aneroid in the pocket and note occasional readings of it. The aneroid might be useful when a

sketch could not be made. A staff officer in action, in deciding hastily on the best position to put guns to command the front, would, I think, find it particularly so.

But although I have found the rule surprisingly accurate in many instances, it can only be depended on in settled weather.

In conclusion, the points I should like to hear discussed are the following:—

1. The practicability and utility of a scale of shade.
2. The necessity of the conditions on which I base a scale of shade.
3. The truth of the axioms assumed by me.
4. The construction of the scale of shade.
5. The application of the scale of shade in the field.
6. Contours and hachures. Their relative value.
7. The aneroid barometer applied to levelling.
8. Pictorial effect.

E. R. J.

COMPARISON OF SCALES OF SHADE (See Pl. IV).

No.	Principle of Construction.	Maximum Stroke at 45°.	Minimum Stroke at least inclination expressed.	Proportion of Shade to Light at 45°.	Proportion of Shade to Light at 5°.
		inch.	inch.		
1.	Sine and cosine	$\frac{1}{45}$	$\frac{1}{365}$	equal	1 to 11·5
2.	Two Arithmetic Series.—No. 1...	$\frac{1}{45}$	$\frac{1}{405}$	equal	1 to 81
3.	Two Arithmetic Series.—No. 2...	$\frac{1}{45}$	$\frac{1}{405}$	2 to 1	1 to 40·5
4.	Tangent and cotangent.—No. 1...	$\frac{1}{45}$	$\frac{1}{516}$	equal	1 to 131
5.	Tangent and cotangent.—No. 2...	$\frac{1}{60}$	$\frac{1}{689}$	equal	1 to 131
6.	Lieut. Colonel Scott's..............	$\frac{1}{60}$	$\frac{1}{600}$	2 to 1	1 to 21
7.	Captain Webber's	$\frac{1}{45}$	$\frac{1}{400}$	5 to 1	1 to 8
8.	Captain James's	$\frac{1}{45}$	$\frac{1}{405}$	equal	1 to 161
8*a*.	Ditto ditto (1st variation).	$\frac{1}{60}$	$\frac{1}{540}$	equal	1 to 161
8*b*.	Ditto ditto (2nd variation).	$\frac{1}{90}$	$\frac{1}{900}$ *i.e.* theoretically	equal	1 to 161
9.	Compound Scale. Altitude and inclination with pictorial effect.	$\frac{1}{45}$	$\frac{1}{405}$	varying	varying
10.	A pictorial scale adapted to inclination only, and constructed to a graduated system without rule	about $\frac{1}{45}$	about $\frac{1}{600}$	about 4 to 1	about 1 to 8

DISCUSSION ON PAPERS II & III.

GENERAL SIR J. F. BURGOYNE, BART., G.C.B.,
&c., &c., &c.,
IN THE CHAIR.

LIEUT. COLONEL SCOTT having been asked by the chairman if he had any observations to offer on the papers which had been read, said:—I have this observation to make, Sir. During the reading of these papers I felt uncommonly like an enemy who had been foolish enough to write a book; I have only one or two remarks to offer in defence and explanation of my folly. The special object with which I wrote my paper was to advocate the use of one scale of shade throughout the army, and I thought it of importance therefore that the scale adopted should be such as would well express the manœuvring slopes. I felt, however, that whatever the method in which such a scale might be drawn up, it would be utterly impossible that draughtsmen could follow it so accurately as to enable others to read correctly, from the scale alone, the inclination of the ground represented. It seemed evident to me, nevertheless, that one must arrive at more accurate results, if one scale is made use of, than if every man draws just as he himself fancies at the moment.

THE CHAIRMAN: Do these gentlemen differ from you at all?

LIEUT. COLONEL SCOTT: I have some difficulty in ascertaining whether they do or not. They *have* differed from me at some period of time; Capt. James differed from me two years ago as to the question whether one scale of shade only was used on the Ordnance Survey. Capt. Webber altogether differed from me two years ago as to whether a scale should be used or not. He then thought not. I am happy to see that in the main points I have made him a convert. Capt. Webber is now using a scale of shade, and thinks it a valuable thing. I have always been of opinion that a scale of shade, as I have already said, could not be used with such accuracy as to enable either the men drawing with it to work accurately from it, or the men using the drawing to interpret very exactly what was intended. It is absolutely necessary in my opinion that you should, either by means of figures on the drawing, or by numbered contours, give the means of arriving accurately at what the slopes may be. In fact you must look upon the shade simply as supplementary to what the contours mark out, its office being simply to lead the eye of the General to apprehend at a glance the general character of the ground. I by no means advocate tying a man down so accurately to the use of the scale in the field as to impede his work; but if we accustom our draughtsmen from the earliest time to associate a certain amount of shade with a certain inclination, we shall certainly accomplish this much—that all the men thus trained will work within narrower limits of error than if they had no such training. With reference to the particular scale of shade I have myself adopted, I think those who have worked with me will bear me out in my statement that I have never laid much stress upon it. In

fact, I have myself modified it since I first introduced it, for I found the instructors at Sandhurst thought that the strokes were too close at its upper extremity for inexperienced draughtsmen. For the scale I first made use of I picked out the different tones from drawings that probably were made by very careful draughtsmen. I measured also the strokes of drawings which had been made by Sappers (Capt. Marsh will bear me out in what I say), and I found that by accurate microscopic measurement the Sappers could draw strokes one-sixtieth of an inch in thickness, and lines as fine as one-six-hundreth of an inch. The particular scale of shade, however, as respects thickness of stroke that may be used, is, I really think, a matter of comparatively little importance; but it is a matter of very great importance, if we tie all draughtsmen to work on the same system, that the scale adopted should be as simple as possible, and that we should not attempt to shew by any alteration of the numbers and thicknesses of its strokes more than the one element. I mean to say if we shew inclination by it, it is as much as we should attempt to do; if we try to combine with this the representation of absolute altitude above the sea level, or the introduction of side light as has been proposed for the Ordnance Survey, we shall go astray. It is a very difficult matter indeed for any man to adhere to ten gradations of stroke; no man in the corps perhaps knows as well as myself how imperfect such imitation is under the best circumstances; still if we have these ten strokes only to deal with, you can conceive it possible that a man may work so as to produce practically the same results as another; but if we vary these ten strokes according to altitude, and again vary these variations according to the direction in which the light is supposed to fall, it is utterly impossible that any ordinary draughtsman can produce reliable work. I will close my remarks by saying I never recommended sketches of country in the field on service to be made on such large scales as I am supposed to have suggested.

Capt. James: Sixty inches to the mile.

Lieut. Col. Scott: I have stated that if such a scale be used I would do so and so, but surely that is a very different thing from recommending it; and if I am asked why I introduced the mention of a scale of 60 inches to the mile at all, I think I could give a very good reason for it. I have been a good deal engaged in giving instruction in this subject, and, as an instructor, I felt it an important matter to keep all those under instruction under my eye. If you can get such a thing (and really they have it in the hills around Sandhurst) as a large model, and make the people under instruction work over this, you can keep the operations of the whole party in check; and you will find it also, for other reasons, better to begin to teach them on a large scale. It is better gradually to reduce the scale than to begin on a small one. I have, however, not the least intention of recommending any larger scale than six inches for work done in the field. With reference to an omission in my paper—which has been criticised—that I have said nothing about the aneroid barometer in it; I can only say I had no intention of writing on that subject, but desired to write on the subject of a scale of shade and the importance of introducing one into the service. I have now only to repeat that so long as we have *a* scale of shade I shall be satisfied, but I do think it is of some importance that that scale of shade should be such as is pleasing to most men who draw well. I consider that the scale Capt. Webber recommends is, if I may use the term, too raw; that for the thickness

of the strokes there is too much space between the lines. Not only do the cadets appear naturally to draw more like the scale I recommend than that which Capt. Webber recommends; but there is a drawing in this room which is executed on Capt. Webber's scale by an officer of Artillery, an instructor at the Academy, which bears out my notion. This officer was aware that the drawing was being watched while he was using the scale he advocated in opposition to mine, and, notwithstanding this, he has produced a result which looks more like my scale in its shade than Capt. Webber's. I would particularly also call your attention to the sketch on the wall executed by Major Petley, which I consider is really a fair specimen of what may be produced by my scale of shade. When I term it *my* scale of shade, I must recall to your mind the fact that I have, in fact, taken it from good Ordnance sketches, combined with the sketches made by Major Petley and other confessedly good draughtsmen. It is no wonder, therefore, that when they use this scale they should produce results as pleasing as those which they formerly produced.

Capt. Hutchinson, R.A.: With regard to the remarks made by Lieut. Colonel Scott upon my drawing for the Council of Military Education, perhaps, Sir, you will allow me to explain that I made use of Lieut. Colonel Scott's scale of shade at least a year before Capt. Webber's was put into my hand, and this may account for some of the gradual slopes assimilating themselves more nearly to Lieut. Colonel Scott's scale. I most certainly endeavoured to carry out Capt. Webber's, and I think upon a critical examination the drawing will be found to deviate but little from that officer's scale.

Capt. Binney: Perhaps I may be allowed to make one or two remarks. I desire to say I quite agree with Lieut. Col. Scott as to this, that it is not a matter of any importance from whom the scale comes, or in what way it is formed, so that it produces the effect required. I think, Sir, that what we want is a scale that shall really express the ground with something like accuracy, and be capable of being easily read, and I do not think that we get this power of reading from Lieut. Col. Scott's scale as readily as we do from Capt. Webber's. With reference to the flatter or lower slopes, you require, as a rule, a far greater amount of distinctness than you do in the upper slopes. You require with these so-called manœuvring slopes a far greater amount of difference than you do in the others, because, for the purpose of moving artillery and such matters, you ought to know whether the inclinations are suitable or not; and it will be seen that, in Capt. Webber's scale, there is a far clearer distinction between the slopes from 15° downwards than there is in Lieut. Col. Scott's. I think that is a point of very great importance. When you get above 15°, it becomes of comparatively little importance, though, perhaps, from 15° to 25°, it is necessary that there should be some tolerably marked distinctness; but above 25°, in my opinion, it is of very little moment whether the slopes can be accurately read or not; and, if so, it is little matter how close the strokes are together. I think they are quite distinct enough in Capt. Webber's scale, and, I may say that the stroke in Capt. Webber's steeper slopes, to which exception has been taken, is not impossible, or even really difficult, to make. With reference both to Capt. Hutchinson's drawing and the drawings of the cadets here, I repeat what he has said already, that the difficulty arises from the

fact that Lieut. Col. Scott's scale, or a scale similar to it, was for some time in use before Capt. Webber's scale had been attempted; and that, even at this moment, the cadets are taught the first part of their work from drawings made by Major Petley in connection with Lieut. Colonel Scott's scale, for this reason, that Capt. Webber's not having been authorized, we have not been able to have a set of copies properly prepared for them to work upon. I do not profess to be a great draughtsman, but what I desire very much, as having charge of the work at Woolwich at present, is to have now settled a scale which may ensure the capability of reading ground, and with great deference to Lieut. Colonel Scott's opinion, I *do* think that we *can* have a scale by which both the inclination and the altitude of the ground can be seen. I would not do away with figuring the highest points of all commanding positions, but would put the numbers in feet clearly and distinctly; yet, at the same time, I think you might read all the flatter slopes at least, by simply applying the scale to the drawing if made with moderate care. The specimens which we have at present, even the best of them, are not fair tests of what may be done by that scale, because there has been so little opportunity of getting one's hand into practice with it; but I am quite satisfied that with a fair amount of time and correct copies at the commencement, we shall be able to bring the greater part of the cadets at Woolwich into complete accordance with the scale, without any real difficulty at all. The difficulty hitherto has been to get their hands out of a scale they have already learned, and out of a wrong way of working into that which we now desire to carry out.

COLONEL LEACH: Although I have had considerable experience in contouring and hill-sketching, I have had little experience in teaching; I can, however, quite understand the importance of a scale of shade for the purpose of teaching and instructing beginners; it would no doubt also be applicable, and of great value, for rapid sketching in the field for a General Officer, where, perhaps, the more mechanical you can make the work the better, anything in the way of artistic representation of the ground being unnecessary; but in considering its value with reference to larger purposes, such for example as the Ordnance Survey, I do not think an arbitrary scale of shade could be introduced with the same advantage. In large surveys, embracing large areas, you have to deal with every possible variety of ground, from the lowest levels up to altitudes of thousands of feet, and I should doubt the applicability of the system under such circumstances, and its power of bringing out the great features of a country, and giving that varied and artistic expression which is necessary to produce a good map for general and geographical purposes. There is one point connected with the representation of ground for military purposes I should like to dwell upon—the value and importance of contours. I believe that an educated eye will read a map with contours alone with as much facility as it will read a hill-shaded map; and that the knowledge of the ground obtained from the first will certainly be much greater and more accurate than could be obtained from the second. The most accurate information which could be given to a General Officer would be a contoured map, with the intervals between the contours marked in feet, and as every officer now appointed to the Staff undergoes a course of instruction in topography at the Staff College, we may assume that in a short time every Staff Officer will be able to read a contoured map with facility.

It is true that a shaded map conveys a more rapid impression of the general character of ground, and for geographical purposes this is desirable; but a General Officer cannot act upon impressions, he must study and know the ground upon which his troops are to operate, and anyone able to read contours would never dream of trying to obtain this knowledge from a hill-shaded map when a contoured one was available. To make proper use of a scale of shade, and to obtain from a map so shaded the full amount of information it is intended to convey, special education is as much required as it is to enable a contoured map to be read with facility. It is as necessary that the eye should be instructed and accustomed to read the one as the other, and as special instruction is admittedly necessary, should not the preference be given to that method of representing ground which conveys the most accurate and perfect information. I would therefore suggest that the point of greatest importance, and which ought to be the most carefully considered with reference to the system of education to be adopted, is whether it would not be desirable to introduce contouring and contour-sketching to a larger extent than is the case at present. If I understood aright, Captain Webber proposed to cover the contours by the shading, even when the former had been inserted on the field sketch. I should say on the contrary, let the shading be subordinate to the contours. There is one other point in Captain Webber's system to which I would allude—the introduction of paces as a measure of altitude. The introduction of special measures for the imagined convenience of particular classes has led to considerable inconvenience to the public at large, and is to be deprecated. I therefore submit that it is better to adhere to the ordinary measure of feet which is familiar to all.

Capt. Farrell: I should be glad to make a few remarks on this subject, inasmuch as the two papers that have been read to-night are, to my mind, a distinct innovation upon the old principles of sketching in the field, and, I believe, that they are likely rather to do mischief if the principles advocated in them are carried out as proposed. Considerable progress appears to have been made of late years in the correct delineation of ground, due for the most part to the employment of contours as a basis. It is now proposed to extend that system of contours, and there appears to me to be no little danger of its impairing the efficiency of the military sketcher. As I understand Captain Webber's system, and Captain James' also, it is nothing more nor less than the multiplication of contours. Now it has been said by a person who has given great attention to this subject, "That by a contour "system alone definition of ground is purely symbolical, and that one fatal "defect among many others of less importance is, that the eye catches little "or nothing at its first view; no immediate notion of the lie of the ground can "be formed, and a sense of substance and relief can at last be gained only by "some strong effort to grasp" and get together the wandering lines of contours. It is a decided strain upon the imaginative powers. It is quite certain that General Officers are not at all partial to this system of contours, neither can any man but the Engineer view it favourably. I agree with Lieut. Colonel Scott that the shading is essentially a supplementary art; it is simply for the purpose of grouping together the contours, gathering them up in a mass, and presenting them at a "coup d'œil," and at once you take in the subject, and learn all the accidents and peculiar features of the ground. Admitting the objection

above made to contours alone, we may enter upon the subject a little more closely; we may say that they are but imaginary lines, that they have no natural existence, that they are run out at arbitrary elevations of say, five, ten, fifteen, or twenty feet, irrespective of any actual lines on the ground. Therefore it follows that they do not give the lines of the greatest and most marked characteristic importance. These great and important lines, traceable at sight in every landscape, features of the utmost value and importance, whether they are received at a glance or more searchingly traced out by the geologist, (that is, by one who actually understands the form of ground), are never caught and transmitted to paper except inasmuch as they happen to "intersect" the contour line, which is only the horizontal line. I had charge of the contour department of the Ordnance Survey for many years, and I know that when a contour map is inspected, it does not at first sight shew out the natural features of the ground. Lines that have a name and value, geologically speaking, that are looked for by men who understand the form and surface of the earth, are not traceable. These contours may omit main features of the ground, which sketching can alone supply. I believe that Sir Henry James, the director of the ordnance survey, holds this opinion; he has large parties of men employed to take sketches of the natural features of ground. Colonel Leach will probably remember that this opinion was arrived at when an English map, shaded from contours alone, had failed to render characteristic features of the Craven district. Now subsequently a drawing of the same district was made from hill sketches; and, without any local names at all being affixed, it was once shown to Mr. Warrington Smith, who immediately told us what country the drawing represented. Professor Phillips, reader in Geology at Oxford, was equally correct as to another picture of another district. Therefore I maintain, without fear of contradiction, (for if contradicted I would simply say, let results be brought forward and let the question be decided by results) that our Ordnance Survey system provides a higher standard; that it will produce the very best work; that it is in accordance with the system of Mr. Dawson, who, without the help of contours, without all the means and appliances we have at the present day, turned out the most beautiful work, which even at this very day will hold its own with others. And I say that he arrived at that excellence by long experience. The only point of difference between Lieut. Colonel Scott and myself in sketching ground is simply one in which I follow Mr. Dawson, which is that the idea of elevation of ground can be attained on your picture by some consideration of perspective. It is very difficult to enunciate anything of that sort, and I simply say that it can be done in opposition to the bar Lieut. Colonel Scott puts upon it in his system, wherein lies the only point of real difference between us. He says, "Have no respect to elevation." I am very happy to have heard to-night that General Jarry in his lectures always said that the relative command of ground was most important. It has always been ignored till to-night by the officers who wish for this contour-system, and I am glad to find both General Jarry and Mr. Dawson place it, as I conceive it ought to be placed, in a very important position. It simply remains with yourself, Sir John Burgoyne, to state whether we shall at once depart from Mr. Dawson's system—the fruit of forty years experience—for between Lieut. Colonel Scott and myself I believe there is no other difference. It will, in my opinion, be a very

strong measure to upset the system that Mr. Dawson was enabled to introduce, by which he brought forth such excellent work. I think it must be apparent to the meeting that if you are to go out and run contour-lines, as Captain Webber proposes, it must take a long time. He has not told us at all how he does it, but the very quickest way, I suppose, would be to take sectional lines; I do not suppose that he threads round the contour, but he may take sectional lines and join the points. But that is a very lengthy operation, and although the estimates of time that he requires have differed to-night from what he published in his last paper, I simply say it is quite beyond my power to reduce them to anything like a practical basis, such as would help us to arrive at some conclusion on that most vital point, as to whether the proposed system will or will not be sufficiently expeditious. For instance, Captain James has charge of a number of men who have been for the last eight or ten years hill-drawing. They have a plan put into their hands which has every detail marked—road, hedges, fences, every conceivable thing, even contours—and yet those men working for their bread cannot work within one-twelfth of the time that Captain Webber stated in his paper would suffice. With such a very wide difference it becomes impossible to say that either Captain James or Captain Webber have given us sufficient data to determine the question I would raise as to whether the "contour" system is sufficiently expeditious. I think working by a scale of shade would be most laborious and most irksome to the officer, and is most deficient in its results. It has never yet produced a plan that can be put side by side with others. It must be admitted that when beginners work over contours they naturally work from one contour to another, and so leave a terraced edge at each contour. At Woolwich they find it so difficult to obviate that evil that they put in what they called "guiding lines." Captain Webber states that it is a difficulty very soon got over, that it is the "*pons asinorum.*" There is only one man in England, Major Petley, who has ever got over it properly, therefore I think it is rather hard measure to call it the "*pons asinorum,*" since he is the only man that has ever crossed the bridge. There is not a single drawing on the new system that gives anything like a full description of ground. Those contours shew the *undulations* of surface, they do not shew one single natural line. I think it only requires inspection to make that point perfectly clear. I have not quite elucidated the argument, but I think it should be tested on its merits, and especially in respect of time. An inferior standard of work, together with greater expenditure of time, are the short objections I see to the proposed system. There is nothing to be said against the scale of shade proper; but there is this to be considered which I have not alluded to, so little would I prejudice people against it, viz., that Major Petley is of opinion that the scale of shade will destroy the free hand of his pupils, and that nothing improves the young men so much as to "eye-sketch," *i.e.*, to go out without instruments and to draw in ground. General Napier (who desired me to apologize for his not being here to night) has had very large experience, and he always looks in the batch of officers joining the Staff College for those men who have been taught as cadets, and whose hands were early trained to the work. This scale of shade will destroy all freedom of hand. There is not a drawing-master that will allow his pupils to do drawing by rule, but he will first teach the eye to apprehend form and the hand follows the eye. I

am sure every draughtsman in this room will believe that if a man is to draw by scale of shade and by guiding lines, he must lose all freedom of hand.

Capt. Hutchinson, R.A.: I am surprised that no reference has been made during this discussion to the system carried out in foreign armies. A short time previous to the publication of Lieut. Colonel Scott's scale of shade in the Corps Papers, General Sandham obtained permission for my visiting the Military Colleges in Austria, in order that I might make myself acquainted with their methods of instruction in topographical drawing. At Woolwich, at that time, we were making use of Mr. Dawson's pictorial system, and I had never seen a scale of shade employed. However, one of the first remarks made to me by the General Officer in charge of the Staff College at Vienna, was, that in consequence of their scale of shade, they had (speaking roughly) no failures, but that every officer, on leaving, was able to depict ground correctly. The same result was apparent at their Cadet Academy, at Wiener-Neustadt, where 400 young men were under instruction. Some of their drawings, from models, were most beautifully executed; even their weakest draughtsman produced a very fair idea of the original; and the fitting together of different portions was very successful. I also saw the young officers sketching in the field, and I put to the Staff Officer who was instructing them a somewhat similar question to that of Capt. Farrell, viz:—"If you are so tied down by a scale of shade, how can you ever produce a free, and yet rapid, sketch?" He said, "The students become so apt at representing the various slopes by means of the scale, that they find no difficulty in applying it, even when pressed for time, and when no scale is in their hands to assist their memory." Shortly after my return, the cadets at Woolwich were instructed in the use of Lieut. Col. Scott's scale with the most marked success; for, while formerly only the good draughtsman had any chance of really excelling, the bad soon giving it up as hopeless, now, those who have no particular talent for drawing, see at once that, by perseverance and study, they can successfully compete with the others.

[*The discussion was then adjourned till the 6th June, 1866, when it was resumed, General Sir J. F. Burgoyne being again in the chair.*]

Lieut. Col. Fisher: I am sure there can be very little difference of opinion amongst the officers present to-night as to the great value of a scale of shade for representing relative slopes of ground. I think we are all unanimous on that point. Even Capt. Farrell the other night, though he objected to the employment of a scale of shade, made a remark* afterwards that if he was to send out a certain number of men to make joint work which was to be put together, he would give them a scale of shade to work with.

Capt. Farrell: A sort of scale of shade.

Lieut. Col. Fisher: As regards the practicability of using that scale, and getting men accustomed to it, we have good testimony. Capt. Binney has told us that, in the lower classes of the Academy, the cadets were taught to draw plans in which the fine strokes predominated, and that it is extremely difficult to get them out of the habit of making fine lines, and to use the thicker strokes required for Capt. Webber's scale. Capt. Hutchinson, R.A., tells us that he drew for

* This remark was made in answer to a question addressed to Capt. Farrell as he was returning to his seat after speaking. The short-hand writer did not catch either question or answer.—Ed.

a year on Lieut.-Col. Scott's scale, and that he finds it extremely difficult to get out of that scale to Capt. Webber's. He also tells us that the Austrian officers and men have got so accustomed to a scale of shade, that, when pressed for time, they are able to represent the different slopes with great fidelity, without employing the scale in the field.

I think, therefore, there is no doubt that you can get men, by habituating them to a certain scale of shade, representing different slopes, to delineate ground in such a way that their sketches, as regards tint and general effect, should agree so well that they might be put together as an entire work. But there, I think, we should drop the scale. I think it is a question of drawing and a lesson that should be taught from the beginning.

When you commence to instruct cadets in representing ground, and hill sketching, their most elementary drawings should all be on the scale of shade which you propose to adopt, whatever that scale may be; but afterwards, when you come to actual operation in the field, I do not think it is practicable or desirable to employ such a scale when working. I think it will be quite right, from time to time, as a matter of exercise, to draw plans according to the scale, in order to keep the hand in; but I do not think it is right or desirable, proper, or even possible, to tie down an officer working in the field by saying, "Here is a scale of shade, you must work according to it, and your plan is to be read by it."

This is a point where I think Capt. Webber and Capt. James both go a little too far. They are led away by the advantage of the scale of shade, and perhaps by the term scale—a term which implies a thing with which you can measure—and they propose, (I think I am not wrong in saying this), they both propose that the slopes of the ground on the sketch should be measured by the scale of shade. I consider that the hachures which are based on that scale are simply employed to get the *c up d'œil*, to give such an effect to the representation of the ground as to enable the person, for whose use it is made, to embrace the whole of the bearings of the adjacent features at a glance, more readily than he could were contours alone indicated; but the actual fractional values which the officer wishes to give to the slopes of the ground, in order to know what arms he may manœuvre upon it, should be given by the horizontal intervals of contours, and may be easily read by means of a scale of slope.

I think we are all agreed as to the horizontal system being the right one, and if the sketch is anything more than a hand-and-eye sketch, the officer who makes it, having with him a compass and small pocket level or kind of clinometer, is able, with very little difficulty, to trace approximate contour lines. In every military sketch these contour lines should be shown in a marked manner, probably by hard red lines running over the plan; and over these lines should be superimposed the hachures, drawn according to the officer's experience of the scale of shade.

What I mean by a scale of slope, is this:—The officer who makes the plan has no difficulty whatever in making a horizontal scale of feet or yards on that plan, and it is perfectly easy for him, with that horizontal scale before him, to make a scale of 1 in 5, 1 in 10, 1 in 15, or 1 in 20; or, in other words, a scale of bases to those different fractions. For contours at vertical intervals of 25 feet, for 1 in 5 he puts a horizontal measurement of 125 feet; for 1 in 10, of 250 feet;

for 1 in 20, of 500 feet; and so on; and the General Officer, who looks at the plan, sees the horizontal interval of the contours, and can compare it with the simple scale which has been made. If it is considered preferable to give the slopes in angles, the scale would be one of the cotangents of certain angles, which would be readily learnt.

Capt. Webber speaks of applying the scale of shade to read the slopes, and Capt. James speaks of copying it on to the sketch; as regards the first idea, it is possible that the person using the sketch may not have a scale by him; and as regards Capt. James's idea of reproducing it, that is a thing not by any means easy to do, and when done, it is extremely difficult for the officer who inspects the sketch to be able to compare a small pattern of hachures on one corner of the paper with a large tract of shade upon some other part. It is almost impossible to compare two things of that kind without superimposing the one on the other. If you trust for measurements to a scale of shade drawn upon the plan, I do not see how the General Officer can readily acquire any good idea of the gradient; but by having a scale of slope independent of the hachures, you get something of real value for the inclinations of the ground, about which there can be no difference of opinion.

If an officer working in the field has, in addition to his compass, a small pocket level, or some instrument of the nature of a clinometer (such as Casella's altazimuth instrument, where the compass and vertical arcs are combined in a small space), he possesses every facility for tracing contours, and running sections here and there from the low to the high ground; he can also give the relative heights of the different features; he is able in fact to get an immense amount of information upon the sketch with very little additional trouble to himself. There, I think, is the great difference between the good and the bad sketcher. The good experienced hand, who appreciates the form of ground, would be able to put, in a given time, very much more useful information upon the sketch than the inferior one is able to do, though, as regards details of drawing, the two sketches may be equally correct.

If I may be allowed, I should like to say a few words about the belt sketching as taught at the Royal Military Academy, by Captain Webber. The fundamental principle, as regards compass sketching, and all sketching, is, that you should sketch upon long lines. The instruction that has always been given to the young officers at Chatham is to avoid traversing, and using many angles and short lines; but to take a long bearing right through the ground, checking your pacing along that line by cross bearings to known points, and getting in your details on either side by interpolation. That is the system employed in getting the details, but it is not the whole operation of military sketching.

The first point in military sketching, as in all surveying, I conceive to be, to fix the position of a certain number of points with the greatest amount of accuracy possible; the next thing is to get a general idea of the features of the whole ground; and then the third is to set to work with the compass and sketch that ground, running as long lines as possible. These three operations may be performed simultaneously by a good sketcher.

Capt. Webber is quite right in the system of going along on one long bearing straight over the ground, but that is only a portion of the operation of making

a topographical sketch, and I do not think that a cadet who has learned to sketch a belt of ground, clever and capable as he may be, would necessarily be able to sketch a tract of country. He has already a knowledge of the process of the *sketching*, but he has not learned the art of studying ground. It seems to me like the end of the last lesson rather than the first.

I admit that after he has learned to sketch, it is extremely valuable that he should be able to apply that knowledge to the rapid, simple combination of a number of sketches. Lieut. Colonel Scott's idea, when some years ago he introduced a scale of shade, was mainly that of getting sappers to work together, representing ground in such a manner as to admit of their work being joined.

LIEUT. COLONEL SCOTT: It was introduced first with that idea.

LIEUT. COL. FISHER: The application of Capt. Webber's method is very good, simple and legitimate. I think that it is quite right to have a simple mechanical system of representing ground, which would enable you to put it in the hands of men comparatively unskilled when compared with Engineer or Staff officers. It is an exceedingly valuable thing to be able to do that; but the victory which Capt. Webber considers he has gained at the Academy in perfecting this system, looking upon it as a question of education, is gained, I think, through the extremely low standard at which he has aimed. It appears to be reducing the cadet to the level of the sapper. You profess to teach Woolwich cadets to become Engineer or Artillery officers, and I think you should expect a little more from their intellectual attainments than to be capable of performing a simple, mechanical sketch. The mere fact that 80 per cent of the cadets who go through Woolwich are able to sketch one as well as the other, may, perhaps, be considered condemnatory of the system—*i.e.* as a system of instruction to officers—rather than the reverse. I cannot conceive that there can be that amount of equality in the capabilities of the different cadets. It appears to me that for such pupils it is a low standard of sketching, simply to take a line and run it straight through the country, without any reference to the features right or left of the limits of the belt. The man who has done it has not got a comprehensive idea of the country over which he has worked.

I should like, if making a military sketch, to get the prominent points fixed upon my paper by means of a rough triangulation; to sketch, with the help of a pocket level, approximate contours, drawing them in with a hard red line, and figuring the heights; while I was doing that, supposing I had been taught to draw upon a scale of shade, I should like to etch in the hachures over the contours according to the best of my memory in accordance with that scale. I would leave the contours as they were originally sketched, for information as to the actual gradients of the ground, and I would trust to the independent hachures drawn from my own head, and my own knowledge of the scale of shade, for giving the general effect or *coup d'œil.* I believe that a series of sketches thus made, by persons accustomed to the same scale, would bear such a resemblance, in tone and effect, as to admit of their being joined and forming an harmonious plan.

In making these remarks, I have wished to point out how I consider that a

separation should be made between the scale as a drawing scale, and the scale as a means of conducting the operations in the field. I think that they are two distinct things, and that it is by forgetting this that some of us have fallen into a mistake; that we expect too much from the scale; instead of looking upon it as a conventional gradation of tint, it has been regarded as a working scale for the field.

Captain Marsh. I think it must be borne in mind in considering this question, that the work done by cadets is a maximum of effect, as far as mere drawing is concerned, because they all get credits for it. Again, if they are emancipated from work which requires thought, and are enabled to concentrate all their power upon the drawing, the drawing will be all the better, and therefore the drawings exhibited no doubt show, in a very high degree, the merit of a scale of shade; and nobody can look at them (especially the one from the model) without saying they give all necessary relief to the ground without any reference to side light. But in considering this question, the contours themselves and the filling in between the contours are two very distinct questions, as has been admitted by all. In Captain Webber's scale, however, as at present constructed, they are both bound up together. He proposes to take a pace of an arbitrary length, to double that space as an arbitrary height of the eye, and to run that through the whole corps of sketchers to the British Army; and I believe, under correction, that such has been the course of instruction in the Academy; that every cadet, high and low, has gone out upon that footing, with a scale graduated to the 33rd of an inch, because the 33rd of an inch upon the 6-inch scale is 10 paces of that arbitrary length, and upon this assumption is based the scale of shade for filling in a drawing of these contours. Now, Sir, we are all prepared, with almost no exception, to accept a scale of shade and carry it out very fully. I speak for myself most heartily. It may be Lieut.-Colonel Scott's or it may be Captain Webber's; but we are not prepared to go into the field and suppose that our eyes are necessarily 5 feet 4 inches in height, or that our pace is necessarily 32 inches in length. Therefore, I hope, if Captain Webber's scale is adopted, it will be modified in that respect at least. There does not seem to be any just reason why an arbitrary unit of that sort should be adopted. Colonel Leach, who as a survey officer, has had, perhaps, as large an experience as anybody, said only a few words the other evening, but very much to the point. He approved highly of the use of contours. He considered the adoption of a scale of shade as a question of instruction only; and he remarked that there was a proposal to adopt a new unit, which required much consideration. Now it is especially to that point of the "*new unit*" that I would call the attention of officers. I think myself we are not prepared to adopt a new unit. We have got a military pace of 30 inches, which nobody can step accurately, and we have got feet and yards, and we are not prepared to adopt a new pace of 32 inches. A pace of four links is a very common pace indeed for sketching on the survey, and it works out very simply; 2,000 of these paces go to the mile, and each pace is 2·64 feet. The pace Captain Webber proposes is 2·66 feet, which works out to 1,980 paces to the mile, and as the other is 2,000 paces to the mile, there is but little difference. I therefore hope Captain Webber will modify his scale to meet existing units, and not propose a new one.

COLONEL SIMMONS: I quite agree with Captain Marsh that it is most desirable we should not have another unit of length introduced into the service. At the present time in the army, great trouble is taken to instruct men in the management of the rifle; they are drilled to a very great extent in judging distances, and all distances are judged in yards. General Officers, when they examine plans, and when they decide on their movements in war involving estimates of distances, do not have recourse to paces when the distances are considerable; paces are never thought of except for very short distances, such as the number of paces in the front of a battalion or company; but directly you get to practical ranges, such as will be used in the field, you always speak in yards; therefore I think it is very objectionable, in any plan whatever for military purposes, to have any other scale to which a General Officer would have to refer. It would bother him, and give him a great deal of trouble in laying out his plans. The great object is to maintain simplicity, and simplicity is to be obtained by reducing our different standards of measurement to the least possible number. Then with regard to the proposition of Captain Webber for breaking up ground in the manner in which he has proposed, in belts, following certain compass bearings, I think that it may be attended with certain advantages in certain positions, but I doubt very much whether you ever will teach people to delineate ground if they are taught to sketch only upon that system. It is very good afterwards, but for first instruction in delineating ground, I think that the principal points to be considered are the features; you want to give those who study sketching the power of grasping the features as nature has formed them. In order to accomplish this, it is desirable that a system of triangulation, with the longest possible lines, should be adopted, so as to establish the main points of the different features with the greatest possible accuracy. After that, in a strange country particularly, I think the system of breaking up ground, as proposed by Capt. Webber, would be exceedingly valuable. You throw in a body of officers, or a number of sappers, and give them certain sections of ground, the details of which they should work out; but that, as Lieut. Col. Fisher has very fairly stated, is entirely a matter of detail, and you will never teach people, by pursuing this process alone, to understand ground and grasp its features. This process tends rather to cramp their powers by leading them to study the detail than to teach them to grasp the large features of the ground. So that I think both systems may work, but each in its own particular sphere.

As regards the scale of shade, it appears that there is very little actual difference in the pictorial effect of the two. I have not studied them both myself with that attention which I should have liked, but it is very satisfactory to learn that an officer has made a sketch, and that Lieut. Col. Scott thought it was upon his scale, whereas Capt. Webber upon his; there can, therefore, be very little difference between the two in that respect. I think that this must be satisfactory to all of us who are seeking a scale of shade, as shewing that we should not be very far wrong in taking either the one or the other. But the principle on which it is followed out is of great importance. I quite agree with some of the observations that have been made, that perhaps "scale" is a wrong term. It is not an actual scale by which you can measure particular slopes, but it conveys an idea to the eye and to the mind approximately, showing the nature of the ground; and it

is of the greatest possible consequence that whatever scale is adopted should be universal throughout the whole army. At the present moment, we are working upon different systems at Woolwich, Chatham, and Sandhurst, and it would be exceedingly awkward on service if a General Officer in command of an army sent out an Artilleryman, an Engineer, and a Staff Officer from the Staff College, to make a combined sketch of ground, and three sketches were brought to him with very different tones of shade in them; because, after all, it is impossible for him to study the contours; to do this, he must have the plan laid down upon a table, with ruler, scale, and compass; he must work at it and study it closely in order to get the idea into his mind. This is a very long process; therefore, he must depend, in great measure, upon the pictorial effect produced by the scale of shade, and whatever the scale of shade is, whatever the process is which is to convey to his mind the idea of the ground, it ought to be the same in all cases; and I only hope the Council of Education, who are represented here this evening so strongly, will, before long, submit for the consideration of His Royal Highness the Field Marshal Commanding-in-Chief, some scale of shade, the use of which shall be made imperative upon the whole service in all its branches.

Captain James: I have been disappointed that very little reference has been made in this discussion to my proposition, that the ground on plans of very small extent, on a large scale, need not, of necessity, be represented in a pictorial manner. As none of the officers who have raised objections have mentioned this part of the subject, I cannot say anything more about it.

It has been said that, you cannot remember sines and co-sines, tangents and co-tangents, in the field. I have no wish that you should do so, but by reasoning onwards from data of this description, I have endeavoured to show how you can deduce a perfect rule of thumb which every officer can apply in the field. It has been argued also that it is impossible to work with so much nicety as I propose. Now, a very important point has been dwelt upon by nearly all the speakers, namely, the great educational advantage of the scale of shade. If our opponents look upon its advantages as being educational merely, surely the more precise we can make it in teaching, the better; and the more perfectly we can fix rules in our own heads, the better able shall we be when we go into the field and throw aside rules entirely, (as we shall have to do, there is not the slightest doubt), to produce a plan which shall be read with ease by everybody.

By my system, I require very few rules indeed; I require the measurement of an inch; every man has an inch here, (*the upper joint of the thumb,* the readiest measurement possible), an inch which he can apply to his paper at once; he can divide it into quarters by eye to obtain his unit of measurement—one inch, three-quarters-of-an-inch, or half-an-inch, as the case may be—and this unit every practical geometrician can rapidly divide into any multiple number of parts. If, for instance, he has to divide a space into 45 parts; he divides it into 5 parts, and then each part into 3, and lastly, each into 3 again, and then he has forty-fifths. Any one can do this on the field in a moment.

Next as to the necessity of pictorial effect in the field; I consider I gain a very great point in small military sketches on a large scale—six inches to

the mile—by sacrificing this entirely. The thickness of the line is not a question of main importance with me; it is the number of strokes only; and in my system the number of strokes is so few that I hardly cover the paper at all. I can work very rapidly; I have never attempted to make comparisons between the rate of work on my system and the rates of work on what we call the "*pictorial systems by scale of shade*," but a mere glance on that plan (Pl. III, ground at Aldershot), will show that there *can* be no comparison; that my work can be done in a quarter of the time that Captain Webber's or Lieut.-Colonel Scott's requires, and the question only is, whether my work would be considered sufficiently good and explicit for a commanding officer. This is a point I gain by entirely sacrificing pictorial effect; but when I do use a pictorial scale, (scale 10, Pl. IV), I produce very perfect results, and I think as quickly as either Lieut.-Colonel Scott or Captain Webber. I merely, then, copy a set of shades. It has been objected that I could not do that, but I only propose to do it when there is time, and the same thing would be done by the other systems; whatever their principle, it would result in having to copy a set of shades.

On the Ordnance Survey, although no scale has been efficiently established, we *have* worked with a pictorial scale. Captain Farrell, who has had a great deal of experience, and who was on the Ordnance Survey several years, has remarked upon the time our sketches have taken to execute. During the time he was there—for he can only speak from his own experience—they did not use the scale of shade.

CAPTAIN FARRELL: I spoke from your own paper.

CAPTAIN JAMES: I said nothing about the Ordnance Survey or the rate of working. I do not think the Ordnance Survey is a matter which ought to be taken into consideration here, because there we are not working against time—extreme accuracy is our first consideration; time is quite a secondary consideration with us.

CAPTAIN FARRELL: You have a system of contours given.

CAPTAIN JAMES: Our men go home if it begins to rain, for fear they may spoil their paper. But the matter having been put in this way, I have taken the trouble to take out our averages, in all weathers, sketching and penning-in included, and I find, after all, the rate of our working compares very favourably, when you consider the matter relatively, with the rates that Captain Webber has described to us. I find that in mountains—in country 2000 or 3000 feet high—we had half a square mile a day, at 12s. per square mile; in an average hilly country, two-thirds of a square mile a day, at 9s. per square mile; and, in flat country, a square mile a day, at 6s. I think the cost of that is as little as the cost of any officer working in the field would be; and of course, if you decrease the rate of working and the cost by making the work mechanical, you expect to bring twice as many men in to do it. I can only say my previous experience on the subject, by rough work which I did on active service, has been much added to by several years' careful study on the Survey, and as I have superintended, I believe, thousands of square miles of sketching in Cumberland, Northumberland, and Westmoreland, the most hilly counties in England, I do not think I could have had better opportunities of studying ground. I have had a number of practical hands engaged under me—men who could sketch and do nothing else in the world, who could not write a gram-

matical letter—but the results that they have produced are results, I believe, which were never before equalled.

Now with reference to the statement that the system used on the Survey has been that of Mr. Dawson. Mr. Dawson superintended the sketching on the Survey of the whole of the South of England; the six-inch scale of England was not introduced until we got into Lancashire and Yorkshire; and the whole of his sketching was done on two inches to a mile. I have stated in my paper that the scale of two inches to a mile is so small that you *must* depend upon pictorial effect and relief—that there is no room in so small a scale to show every slope; it is perfectly impossible; but when we got into Lancashire and Yorkshire on the scale of six inches to the mile, and afterwards to Cumberland and Northumberland, our work of course was a very different thing. I may mention, as shewing the advantages of contours, that at one time it was thought that instrumental contours at 100 feet intervals, with contours interpolated by water level, so as to make the whole at 25 feet intervals, represented the ground so truly, that the sketching could be done in the office without knowledge of the ground, and a large quantity of plans were actually produced in this way. I do not say that they were perfectly satisfactory for the purposes of the National Survey, but it was proved that maps on a small scale *could* be so produced, and for *military* purposes better plans could not be desired. The plans so produced, by men who had scarcely, if ever, seen the ground, are still for sale, and I am not aware that the public have ever detected the difference between them and our best specimens. I should be going beyond the question if I went much more into the details of the Ordnance Survey, and perhaps committing a breach of confidence, but I am sure that no officer in the Engineers, or in the army, if he were to apply in the proper quarters, would have the slightest difficulty in obtaining every information.

Captain Farrell had an opening for an attack on the mechanical system, and no wonder he took advantage of it; but I think we must all observe that he is very much in the minority. But he need not think he is quite in so piteous a case as he seemed to imagine in the pathetic speech that he delivered to us, because we want him still, and I will endeavour to shew how. Suppose we had a number of tactical sketches of a theatre of war done on different plan-scales by a number of different officers or a number of different men, on every conceivable system—some simply contoured, some pictorial, some unpictorial, some done by scales of shade—we might have them done on a dozen different systems, if they were all done by rule. If we wanted to produce a strategic map on a small scale, by means of all these different plans, we should have to send for an artist, and then we could call in Captain Farrell, and we are sure he would do his work well. We know he would take our sketches which had been produced by certain rules, and knowing our rules, would not fail to read them; but when he came to take the sketches of his own adherents, he would have to send for each artist to know what was meant here and there, unless he had been on the ground himself, and then he might understand the work of his own pupils.

Now as to the use of a pictorial scale in the field. This entails a very close study of the ground, and involves a great deal of penmanship; for this reason, I think rough contouring is preferable. It has been stated that no General in the

present day would read contours; I have never heard a General say so; it might be the case that it would be so, though I should be very much inclined to doubt it; but I do not see why we, in trying to improve our knowledge of military matters, should legislate, so to speak, for the ignorance of men; we should endeavour to raise them to our standard, I think. Fifteen officers, or something like that number, are turned out from the Staff College every year, who, we may presume, will be our future Generals. Surely these men will understand what contours are. I think a closely contoured plan is preferable to any other sort, and both Captain Webber and Lieut.-Colonel Scott pre-suppose a certain amount of contouring—the former more than the latter. Now if there is time to do the work as they do it, there is more than enough time to make the contouring more perfect, and to complete the pictorial sketch—as I have said was done with certain of the Ordnance Survey maps in the North—in the office entirely; to do nothing but the contours in the field, and then go in and do the rest of the sketch where there is no danger, on the office table.

To say that a General is to take this rapid conception of a plan at one glance, is, to me at least, not admissible. We should not consider any General worthy of his command who acted in such a hasty way as that. On the contrary, he would have to examine the plan closely and frequently, if time permitted, and he surely could not give less than half-an-hour's study to it previously to the execution of any comprehensive movement. Another objection has been made to contours, that the most important feature of the ground may be omitted. If they were at 100 feet vertical intervals, there might be some reason in this, but if they were at five feet vertical intervals, I deny that you would omit anything of importance. Colonel Leach, who has had a great deal of experience, said that he preferred contours to anything. If there is not time enough for five-feet intervals, make them 10, 15, 20, or 25, and I maintain that equal time spent in contouring and pictorial sketching would produce a more perfect and useful result in the former case than in the latter.

It is impossible to fix any area as a day's work by either of the proposed systems, as consideration must be given to the character of the details, the hilly or rough nature of the ground, the weather, the distance, all the accidents of service; but I should be glad to compete, on equal terms, with any one working on the other system, an umpire being appointed to decide between us with regard to the time on the ground, the time occupied in penning-in, and the comparative usefulness of our plans when finished. The only condition I should wish to make would be, that I should not be required to be artistic.

Capt. Farrell, as has been pointed out to-night by Lieut.-Colonel Fisher, confessed that, in the case of doing work with a section of men, he would establish *some sort of a scale of shade.* I would ask Captain Farrell whether *some sort of a scale of shade* does not imply that he would do hastily what we are endeavouring to do carefully, and whether he would be able to weigh his scale of shade sufficiently in that way. If we establish a scale of shade now, we shall surely have an advantage over him; but I hope that when he has this piece of work to do, he will not forget his promise to establish a scale of shade, because I feel certain of one thing, the first result will be to fully convince him of the use of it.

If I have attributed any opinions to Lieut.-Colonel Scott, not expressed in his paper, I must plead that I was misled by the printer of the Corps Papers. Lieut.-Colonel Scott states that he does not advocate such scales as 60 inches to the mile for military reconnaissances.

LIEUT.-COLONEL SCOTT: I advocate six inches.

CAPTAIN JAMES: There was nothing to infer from the plan by Major Petley* that that was the case, but I am very glad to hear I was in error there, because Captain Webber also has explained away my misconception of his views by appending a foot note to his paper, saying, that *he* only advocates the use of large scales for instructional purposes, so that it turns out, after all, that we all agree. This shows the advantages of discussion. We do not know that we agree, and we find out that we do agree. I only hope the officers who have not considered the whole question critically, will do so, and I am sure *they also* will all agree with us in the main, although they may not in minor points.

Lieut.-Colonel Scott has defended an assertion by himself, that a line of $\frac{1}{500}$ of an inch may be drawn with a free hand. I do not deny that it may be drawn, but I say it will not be drawn on active service. As to my maximum breadth of stroke, I fix $\frac{1}{45}$ in.; he fixed $\frac{1}{50}$ in. I do not consider this of much importance, but I think the thicker you fix the maximum thickness, the more rapidly you can descend from one inclination of the ground to another, so that you can read inclination by means of the thickness of the strokes more easily.

In conclusion, I should like Captain Webber to answer two questions. One is, what is the special advantage of the proportion of 2 to 1 between the length of the pace and the height of the eye? and the other is, how, in different men —say a small man of 5 ft. 3 in., and a tall man of 6 ft. 3 in.—he can ensure their working together with accuracy, with the contour height fixed at 64 inches?

THE PRESIDENT: We are very much gratified by the presence of General Napier. I believe he is well conversant with this subject, which, I am sorry to say, I am not, and if he would favour us with his opinion, I am sure we should be very much obliged to him.

MAJOR-GENERAL NAPIER: It would be premature in me to give any opinion upon this question, as I have not yet made up my mind upon it. The Council of Military Education is now enquiring into it very carefully as a part of their duty, and until these enquiries are completed, I think I should not be justified, as a member of the Council who will have in the end to decide the question, in giving my individual opinion upon a point which must be considered amongst us, as a body, with the greatest care, and with the advice and assistance of every person that we can obtain connected with the subject. But I may perhaps, as a General Officer, irrespective of my position as a member of the Council, say, in a few words (what would come with much greater force from yourself, Sir John), what I consider to be the chief points which a military sketch should present to a General Officer, and, I think, in considering this question of a scale of shade for delineating hills, that it can only be considered with reference to sketches of positions of ground where a General wishes to draw up his troops. I do not

* This plan, as stated by Lieutenant Colonel Scott in Vol. XII, page 164, *is* drawn to a scale of 60 in. to the mile, but it is intended only to shew the effect produced by using a scale of shade irrespective of any question as to the scale of the drawing.—ED.

think it is applicable to a large district of country drawn on a small scale, or to a mere reconnaissance of a road. I do not think that it is applicable to scales of less than four inches to a mile. I should limit it to that, and therefore taking it in this view, I would ask, what are the chief requisites in a sketch for a General Officer? Well, I have not the least hesitation in saying, the principal one is that he should, at a glance, be able to see which is his highest ground, and be able to determine the relative command of the different heights. The second important point appears to me to be that a sketch should lay down accurately and correctly all the military obstacles; and the third and least important point of all is, to my apprehension, the *actual* slope of the hills. I do not think that a General wants to know whether a hill is exactly 5° of slope or 10°. I think all he requires to know is whether it is practicable for his artillery; therefore I think if we establish a scale which will enable a General to appreciate slopes proximately, it will be sufficient. You cannot expect a General to have a measure in his pocket and to apply it to the shaded hill to see whether it has a slope of 5° or 10°. He has no time to do this, and if he had the time, I do not see that it would be of much benefit to him. But he does require to know whether he can get his guns or his cavalry to a certain point, and whether the ground is practicable, or otherwise, for those arms. There is one point, however, which is very necessary, and which has been alluded to by everybody who has spoken to-night, namely, that every officer who delineates ground should delineate it in the same way, so that their work should agree, and that a man looking at a plan drawn by several officers would be able to know what kind of ground was represented. But if there is no scale of shade laid down, every man will draw according to his own fancy; therefore as long as some scale of shade is established, I do not think it is very important what that scale is. The question of deciding upon this scale of shade is one that will certainly come before us hereafter; but, as far as I know of the subject, there is one great advantage, as far as I understand it, in Captain Webber's scale, which is this, that his scale is not only a scale of shade, but a scale for contouring, and that, therefore, when he goes out into the field and wishes to draw his contours, he is not obliged to take any levels at all, but merely takes the inclination of his hill by his clinometer, and then he is able to apply his scale in a way which gives him the actual contours without any vertical measurements at all. I do not know whether Lieut. Colonel Scott's scale can be used in this way or not.

LIEUT. COLONEL SCOTT: My scale is not necessarily dependent on the use of contours. It is simply a scale of shade dependent upon the inclination of the ground, and I should therefore be as well content as respects the production of effects, that it should be applied with a clinometer, as that the contours should be first drawn in; but yet I think a careful delineator of ground will always accustom himself to put in contours first and employ these as the basis on which to apply the shade.

MAJOR GENERAL NAPIER: I think when once the scale is established it should be fixed for all our military establishments, and that there will be no difficulty whatever in training young men to use that scale, if you begin, as Lieut. Col. Fisher (I believe) said, by teaching that scale. Let everyone of the examples, from the first, be drawn on that scale, and let each example be accompanied by sections shewing the slopes in degrees, and then, before the student begins to draw his hill let him draw the sections and see what the degree of the slope is,

and then shade it according to the scale of shade of that slope. He will in time become so habituated to it that it will be a mere mechanical operation with him, and he will not feel the slighest difficulty; and when he goes out into the field he will not even require to take his scale of shade with him, he will know that an angle of 20° is of such and such a shade, and so on. I do not think there will be the least difficulty in applying it either to instruction, or, afterwards, to practical operations in the field.

CAPTAIN WEBBER: Sir, before replying to some of the remarks made in the course of the discussion, I would point out the drawings I have exhibited this evening, which did not appear on the first occasion.

There are the examination sketches of the 25 cadets who hope to be commissioned at the present examination, which I believe nearly come up to the anticipated standard.

There is the drawing made by Captain Farrell, for the Council of Military Education to illustrate his system of representing ground.

There are five surveys made by officers undergoing instructions at the Royal Engineer Establishment, Chatham, which I believe are shaded to Lieutenant Colonel Scott's scale.

And there is a copy of the model of Meyrick, in Kircudbrightshire, made by 11 cadets, and drawn to my scale of shade.

First, with reference to Captain James's system, I may say that I agree with his conditions—1, 2, and 4, and partly with 3 and 5. There is little to object to also in his axioms.

Captain James, in common with Captain Farrell, objects to the use of the same scale of shade for all plan-scales. I would repeat that the importance of adhering to the same strength of touch in instructing mechanical draughtsmen, must counterbalance any slight advantage obtainable from lightening the shade on small plan-scales. The scale of shade should be fine enough to express ordinary ground clearly on a scale of 6 inches to a mile, and I think the safest rule is to alter the scale of the plan to suit the nature of the ground; if the features are bold, diminish the plan scale, and *vice versa* if they are intricate.

Captain James's pictorial scale of shade is far too minute for military purposes, and his military scale runs to the other extreme. For instance, in the latter, the hachures at 5° on 6 inches to 1 mile, are 4 inches apart, expressing only a vertical interval of about 30 feet. Also limiting his expressions of ground to slopes of 5°, thus carrying out his theory, that on military sketches the expression of the ground can only be a conventional projection of the features, as with the other "details."

Captain James in basing his sketching on contour lines, without actually contouring, recommends the running of sections by heights in a way of his own, a process which I have already described as "put out of the question in a rapid military sketch, on account of the time it occupies."

I have drawn from this discussion, that Lieutenant Colonel Scott never contemplated the use of contours in rapid sketching, and in this lies an important difference of opinion between us.

So far as the shading of a contoured plan is concerned, our main difference consists in the construction of the scale of shade we should apply to it, expressed under two heads, viz., 1. In the proportionate value of the light obliterated on any unit of area in plan at the angles shewn; 2, in the mode of distributing that value.

But the application of his scale in rapid sketching, I believe Lieut. Colonel Scott would say, only lies in the sketcher using the value of shade acquired by practice, while following the same process in other respects as heretofore. Whereas I propose to carry out the identical process of contouring and shading over the contours, only in a more rapid and therefore superficial way, that is followed in more careful surveys.

In the one case, uniformity may be produced in the drawings of all who have hitherto come under the denominations of good sketchers. In the other, besides uniformity, I aim at enabling the majority to produce equally good results, a theory practically proved by the drawings I exhibit this evening.

The only reply made by Lieut. Colonel Scott to my objections to his scale, is that he cannot conceive so accurate an imitation of a scale to be possible, as that the inclination of the ground could be read on a plan.

That this applies to the scale proposed by him, I am convinced by the drawings made with it, which I exhibit; and Major Petley, who may be considered the greatest proficient in this art in Her Majesty's dominions, and whose drawings are the only ones which do the scale credit, assures me that it is extremely difficult to imitate it (on the manœuvring slopes) with any exactness.

I have already said that at the lower angles the ground would be read by the distance between the hachures; and I believe, from experience, that my way of adhering to that distance, as the slopes vary, is as simple, and insures as correct drawing, as is the reverse in the case of Lieut. Colonel Scott's scale.

With reference to the "rawness" which he remarks in my drawings, if I rightly understand what is meant, I think that the appearance in question has nothing to do with the coarseness of the scale, but is due to what I have already referred to as a careless or incorrect style of drawing.

I am glad that Lieut. Colonel Fisher would advocate the use of a scale of shade in teaching, and can only understand his inclination to be emancipated from it as quickly as possible, by the results produced in applying Lieut. Colonel Scott's scale to the surveys made under his direction.

I quite agree with him that any officer can construct a contouring scale for himself, and so can officers construct scales of paces and scales of shade to suit the occasion, and invent numerous appliances to facilitate their operations; but I would ask, has not this, so-called, rough and ready way of leaving the learner to find out everything for himself been the custom long enough? Does it, in the end, do more than save trouble to the instructor, and narrow the portals of knowledge to the instructed? We all know that few officers, if pushed to it, will fail to do their work eventually; but the same inducements do not exist in undergoing instruction: hence the instructor, if he desires all to come up to a standard which he believes to be attainable, *must* start with simple rules and conditions, and not leave his pupils to stumble about in the dark, wasting their time in gaining an experience which would be a matter of no difficulty afterwards. Colonel Simmons and Lieut. Colonel Fisher agree in believing that my system of working in straight lines for the attainment of a certain object is a low standard to aim at in instruction. The expression might, on the same ground, be applied to any process according as it was more or less mechanical, beginning with the trigonometrical survey of the kingdom. High or low, I only know it does the work; I have proved it in large tracts of ground as well as in small; it enables me to carry throughout the sketch, without loss of time, a vertical section which fixes the relative altitudes with surprising

approximate accuracy, and to apply a scale of shade. And the use of it, for instructional purposes, has produced a marked improvement in the Cadets' examination sketches, both as regards conception of ground and readiness in going about their work.

Between Captain Marsh and me there *can* be little difference of opinion as regards the length of pace; I have always valued the 32-inch pace in practice at 25 to the chain. The only way in which the use of this pace clashes with the rules of the Service, is, as Colonel Simmons says, when we instruct men to judge distances in it. As the distances in musketry drill are judged in yards, and we do not attempt anything but short measurements, I do not think we shall do any mischief.

Great objection is made to my suggested unit of height being double this unit of pace. That both meet the requirements of the average amongst young men, I have proved by recorded measurements made during a considerable time.

If each man formed his own unit we should surely be equally far from the convenient 60 and 30 in. And if the latter were laid down for general adoption, the majority in endeavouring to accommodate themselves to uncomfortable dimensions, would produce a lack of uniformity in measuring, which would be perceptible even on small scales, where the work had to be put together.

Between Captain Farrell and the promoters of a scale of shade, there evidently exists a considerable difference of opinion, increasing as the latter profess to use contours preparatory to shading. This officer, like a true conservative, sees no necessity for improvement on the late Mr. Dawson's manner of representing ground; in fact he would consider every attempt at reform as a distinct innovation. He does not believe that a multiplication of contour lines will express ground truly, and is certain that General Officers are not partial to them; yet we find him at the same time acknowledging that the improvement in the representation of ground of late years is due to the use of contours; and stating that the idea of ground can only be gained by "getting together and grouping the contours." I think that, in spite of his objections, he concedes all that we desire; indeed his own simile exemplifies our process, for in contouring and then shading on the outline thus obtained, we (like the drawing master) teach to apprehend form, and then to complete the drawing. But Captain Farrell has told you that I have not described how I contour in rapid sketching, notwithstanding my attempt to do so in both my papers. If these do not give some idea of this simplest of processes, I shall be very happy to explain it individually to any officer present.

I am also accused of not adhering to the rate of progress that I first laid down; an analysis of my statements will clearly shew the contrary to be the case. The rate of shading by the Ordnance Surveyor can have nothing to do with the rates I have detailed, but, as Captain Farrell has drawn the comparison, I may be allowed to suggest that a coarser stroke, correctly drawn, would greatly accelerate their rate of working, and from what I have seen of their sketching, I think, be the means of placing in the hands of the engraver a more truthful representation of the ground.

In conclusion, I call upon Captain Farrell to conquer his objections to a scale of shade by gaining a like victory to that which I have described in page 35 of my paper; and I ask him to acknowledge the results of that victory in the drawings I exhibit to night, instead of asserting that it has been gained only by a solitary individual.

PAPER IV.

DESCRIPTION

OF

HOWLETT'S PATENT ANEMOGRAPH,

FOR RECORDING, IN THE FORM OF A DIAGRAM, THE DIRECTION AND PRESSURE OF WIND.

By S. B. HOWLETT, Esq.

In 1851, it was ordered that the principal home and foreign stations of the Royal Engineer Department should be furnished with a set of meteorological instruments, including some kind of anemometer capable of registering the direction and force of winds, as they occur in different parts of the world; but it was found that no such instrument could be obtained, except Osler's, which, owing to its great size and cost, was quite out of the question. At last, after many experiments, and with the assistance of the Astronomer Royal, an anemometer was contrived, a description of which will be found in Vol. I of the present series of Royal Engineer Papers. That instrument only professed to register the maximum force of the wind, but had no means of recording the direction whence that pressure came.

It is now hoped that this want of a portable anemometer, at a moderate price, will be met by the anemograph, which records every action of the air in the form of a diagram.

The anemograph is adapted for being fixed in an observatory; but it is here shewn as a field instrument, strongly mounted on a stand, capable of facing a hurricane. The stand has a horizontal motion to enable the instrument to be placed on the meridian. A tripod stand is perfectly steady under vertical pressure, but, being very weak against lateral pressure, the stand, shewn in Pl. I, fig. 1, has four legs, secured by chains, with a chain in the middle, upon which may be suspended a heavy weight of any kind to ensure perfect steadiness.

The greatest pressure against which it is considered necessary to provide in the arrangement of the anemograph, is 20 lbs. on the square foot. In a recent gale, it was reported that the Liverpool anemometer registered a pressure of 30 lbs. on the square foot; but the truth of the instrument may be doubted, as the newspaper did not say that hundreds of people were blown down in the streets, and that nearly all the chimney pots were scattered. A person of middle size certainly presents as much as 3 square feet of surface to the wind, and a

pressure of 90 lbs. would have knocked over nearly all the people who came in its way; for, by careful experiments with pulleys and weights, it has been found that persons of ordinary size and weight could not, without using their hands, hold their own against a pressure of more than 50 lbs.

The following descriptions, aided by figs. 1, 2, and 3, Pl. I, will probably enable the instrument to be understood.

Fig. 1.—*a.* The base of the instrument is a slate, 12 in. square and 1 in. thick, on which is engraved a circle 10 inches in diameter, divided into degrees, and figured from 0 to 360. Upon this base is fixed a square pyramid made of zinc, having a window on each side, and closed by a shutter.

b. A brass tube, forming a lever, working in a gimbal as a fulcrum in the top of the pyramid.

c. A pencil or tracer, of a proper weight, working freely in the brass tube.

d. A sphere of zinc or copper, capable of being moved up and down, and of such a diameter that the pressure of the wind on its hemisphere shall be equal to the whole or any required portion of a square foot, of course taking into account the ratio of a hemisphere to its great circle when pressed by a fluid.

e. A weight so adjusted with reference to the sphere, as to cause the pencil to express pounds of pressure on the square foot by its distance from the centre of the graduated circle, according as the sphere is down, up, or up with a weight *f* at the top, thus giving three scales.

When the sphere is down, the scale of pressure is 0 to 20 lbs. on the square foot; when up, the scale is 0 to 5 lbs.; and when up, with the weight *f* on, the scale is to 2½ lbs. A wooden measure graduated to these three scales, by actual trials, is attached to the instrument.

For ordinary registers, kept daily all the year round, the sphere should be always down. The other two scales are for experiments, under personal superintendence, on light winds, which have never yet, it is believed, been investigated for want of an instrument that will give correct results.

In action, the pencil throws out from the centre, or zero, a line in the direction the wind comes from, and, in returning, a loop or curved line is formed, and the force of the wind is indicated by the length of the line or loop, so that by laying the wooden scale against the centre of the slate and the end of the loop, the force is read on the edge in pounds pressure on the square foot, and the angle at which the current of air crossed the meridian is at the same time found in degrees on the divided circle, or in the terms used on the mariner's compass.

This instrument is strong enough to bear any hurricane; and to measure any force above 20 lbs., nothing more is necessary than to increase the weight marked *e*, in fig. 1, in a certain proportion.

Fig. 2.—The part shewn black represents the manner in which either a breeze or a storm is recorded, the salient points of which mark the direction and force of the principal currents, which are to be measured by applying the proper scale as before directed.

Fig. 3 shews a remarkable fact which this instrument brings to light. If, while the wind is blowing, the pencil be held on the centre of the slate, and then let go for a few seconds only, we get a figure consisting of several loops, as shewn by the dark lines, from which, probably, no other conclusion can be

PL I

Fig 1

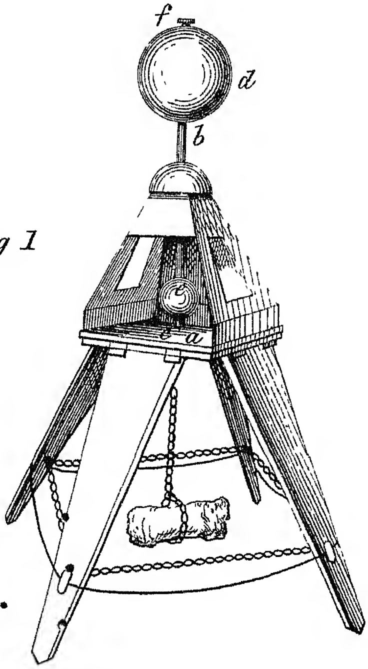


Fig 2.

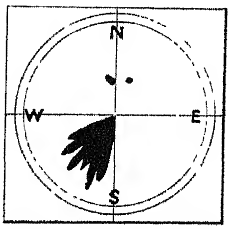
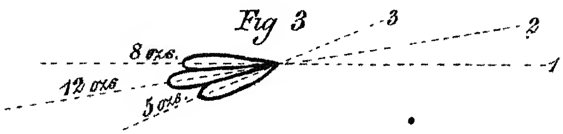


Fig 3



Lithographed at the Royal Artillery Institution

drawn, than that the wind moves on in circles which are constantly crossing the paths of each other, as shewn by the lines 1, 2, and 3. It appears almost certain that if a sufficient number of these instruments were employed in positions accurately marked on a map, that the courses of these circles and their diameters might be laid down on a map; and thus, by studying the small circles, a better knowledge of the law of storms could, no doubt, be obtained.

Maps on common paper may be drawn by the instrument either with black lead pencil or blue chalk pencil; or they may be made on common paper by an agate or a brass tracing point working on carbon paper.

The observer, therefore, can take his choice, either to look at the work on the slate and then rub it out, or to obtain daily maps on paper which would shew in a striking manner the action of the air throughout the year; and the instrument also gives the power of trying experiments that it is hoped will some day lead to important discoveries.

The form of the instrument here described is intended to be as portable as possible; but if intended to be fixed, the pyramid of zinc might easily be so extended as to give cover for the papers and materials.

When intended to be fixed, the instrument should of course be set on the true meridian; but, when used as a field instrument, it may be set on the magnetic meridian like a circumferenter, for which purpose a needle may be sunk in the side of the slate, or a convenient compass provided.

Such is the description of the instrument; but it will after all be supposed that it must be very much inferior in all respects to the magnificent anemometers at the Royal Observatory, at Birmingham, at Liverpool, and other important positions. Now, to enable a judgment to be formed, Pl. II is a copy of a portion of the printed sheet shewing the work of the Greenwich instrument at the time therein stated. It will be noticed that the direction of the wind is not given in angular measurement from the meridian; and it will be noticed that while the enormous vane had power to cause the pencil to mark its changes, the pressure plate was not able to cause its pencil to make any record of the same wind that was recorded by the vane.

At first it was supposed that oscillation would be fatal to the principle of the anemograph; and certainly if the ball be struck suddenly with the hand, a swinging of the pencil takes place, but then, in practice, this tendency is counteracted, for, with rare exceptions, the pressure of the wind comes upon the ball gradually, and withdraws that pressure in a similar manner; and then, too, the pencil is thrown out with little or no resistance, but, on its return, the weight of three ounces, with which it is loaded, acts as a drag, and causes the pencil to stop at zero.

S. B. H.

War Office, Pall Mall,
13th January, 1866.

PAPER V.

ON THE HEIGHT OF COAST BATTERIES ABOVE THE WATER.

By LIEUT. E. M. LLOYD, R.E.

Engineers and Artillerists, both English and French, seem pretty well agreed in fixing about 50 ft. as the upper limit of elevation above mean water for coast batteries.

The reasons given for this are :—

1. That they may not forfeit the advantage of ricochet fire.
2. That a ship may not be able to lie unseen close under their guns.

The latter applies of course only to cases where the battery is within a few yards of deep water.

As regards the former, the height would appear to depend on the angle of incidence which admits of effective ricochet; but while agreeing as to the height, authorities do not agree as to the angle.

Sir Howard Douglas* gives it at 3° or $3\frac{1}{2}$°.

Major General Bainbrigge† says 5° or 6°.

The French *Aide-Mémoire de l'Artillerie*‡ says 4° or 5°.

And the experiments described by Sir Howard Douglas§ shew that shot will ricochet even at 7°, retaining considerable force.

Whatever be the true value, it is evidently made up of the ultimate inclination of the trajectory to the line of sight, and of the angle of depression of this line; the former depending practically on the range alone, the latter on the height also of the gun above the water.

The following is an attempt to shew how this height is affected by the value given to the angle of effective ricochet, and how shifting is the foundation on which the present limit rests.

Table II, of Naval Gunnery, gives the ranges obtained at Deal with a 32-pdr. of 56 cwt., from two different levels for successive increments of $\frac{1}{4}$° of elevation. Correcting these angles for the heights above the plane‖, and tracing a mean curve to the several points thus obtained, we have for

$\frac{1}{4}$° .... 260 yds.
$\frac{1}{2}$° .... 435 „
$\frac{3}{4}$° .... 580 „

as the distances of the second intersection of the trajectory with a horizontal

* Naval Gunnery, § 391. † Corps Papers, Vol. IX, p. 69.
‡ As quoted in the English Aide-Memoire, Vol. I, p. 286. § Naval Gunnery, § 165.
‖ Vide Minutes of the proceedings of the Royal Artillery Institution, Vol. III, p. 18.

line of sight, and these will be very nearly the same when the line of sight is slightly inclined.

Making use of these angles and ranges in the formula for the terminal angle*, the inclination of the trajectory to the line of sight intersecting it at

260 yds.,	will be	20′
435 „	„	35′
580 „	„	50′

Subtracting then the above values from the angle of effective ricochet, and multiplying the tangents of the remainders by their respective ranges, the limits of height resulting are

In order that the 1st graze may be at a range of	If the angle of effective ricochet be $3\frac{1}{2}°$	.... $4\frac{1}{2}°$
260 yds.	43 ft.	.... 57 ft.
435 „	66 „	.... 90 „
580 „	81 „	.... 111 „

Looking, therefore, to ricochet fire alone, it seems uncertain how far its advantages would be lost by exceeding the limit of 50 ft. in height, though the bounds must of course be higher or less frequent, and the loss of velocity at each graze greater. At the same time recent changes in warfare seem uniformly to tend to the depreciation of ricochet, and in favour of a good command. Horizontal shell firing, with time fuzes, is incompatible with ricochet, and elongated shot are ill-suited to it.

The increased precision of direct practice has lessened the need of it, while the introduction of armour-plating, requiring very high velocity for penetration, and the long ranges at which actions will now probably be fought, alike narrow its application.

In fact its sphere would seem to be almost confined to round shot practice at wooden vessels, at from 500 to 1,500 yds. range.

On the other hand, a good command affords the protection to the gunners necessary to meet the improvements in guns, and by reducing their risk, adds to the rapidity and accuracy of their fire.

It, to some extent, frustrates armour-plating, by allowing of a plunging fire on the decks, and improves the chance of a shot passing out below the water line.

It admits of a nearer judgment of distance at long ranges.

It increases the difficulty of enfilade, and will generally make it easier to defend the battery against a land attack.

What is the force of these considerations, and where the balance should be struck, is a matter for experience and authority rather than for argument. But this very fact—that in individual cases the question of height will generally be settled by an appeal to authority—makes it the more necessary that its decision should be reconsidered from time to time. The present limit of 50 ft. is, at any rate, by no means adopted by some naval officers who have engaged coast batteries.

* Boxer's Treatise on Artillery, p. 146.

Capt. Sullivan, in his evidence before the Defence Commissioners, says: "I would throw the battery back inland, so that the ships should not get within 1,000 yds., and, if possible, it should be from 100 to 120 or 130 ft. above the water."

Without departing quite so widely from past maxims, may it not be laid down, as a general rule, that, *although near deep water, a height of 50 ft. must not be exceeded, a battery is most favourably situated for direct action with shipping when it is about 400 yds. within the 5-fathom line, and 100 ft. above the water?* Thus situated, its shot would strike at 600 yds. under an angle of 4°, and the first rebound would, at all events, be effective.

E. M. L.

Hobart Town, January, 1866.

PAPER VI.

AN ACCOUNT
OF
THE FIRE-ALARM TELEGRAPH,
MONTREAL, C.E.

BY LIEUTENANT G. E. GROVER,
ROYAL ENGINEERS.

A description of the means adopted by a colonial city for the suppression of fire within its limits may, at first sight, appear out of place in a publication devoted to subjects connected with the duties of the Royal Engineers. For, whilst the firemen (or *sapeurs-pompiers*) of most Continental cities have a quasi-military organization, and are officered by men selected from the *sous-officiers du génie*, Shorncliffe camp furnishes the solitary instance—so far as I know—of the fire department at any station in England being placed in charge of an Engineer officer.* Nevertheless, I am hopeful that a short account of the Montreal Fire-Alarm Telegraph may be considered of sufficient interest to justify its insertion; since any successful application of the electric telegraph to the organization of disciplined men has claims on the notice of our corps, to whose charge that instrument has been committed for use in military operations; and such an application of it has, in this particular instance, proved eminently successful. And I would mention, as an additional reason for

* These remarks of course apply only to the arrangements made at military stations for times of peace. Napoleon's decree of the 24th December, 1811, Article 94, (relative to the defence of fortified places) lays down that *"Le service de l'Incendie en cas de siège, ou de bombardment, est reglé par le Gouverneur ou Commandant, de concert avec le Commandant du Génie et l'autorité civile."*

considering this subject worthy a soldier's attention, that it is contemplated, at the present moment, to extend the uses of the telegraph to a purely military purpose, that of calling out the different regiments of local militia, in cases of emergency, by tocsin—alarms simultaneously sounded from the church towers.

The general principles of the fire-alarm scheme may be stated in a few words. It consists simply of a means of communicating, from as many points in the city as may be desired, to a central station, whence an instant alarm can be given by ringing large alarm-bells in different places at the same moment, by one person. To do this, there extend over the city of Montreal (which occupies an area about three miles long and one broad) four metallic "signal" circuits, all passing through the central telegraph office in the City Hall, and communicating on their way with sixty signal-boxes, distributed at the corners of streets, or some other convenient places, as shown on the accompanying plan (see Pl. I). To raise an alarm of fire, it is merely necessary to turn a crank in the nearest box, and its number is instantaneously recorded at the central office. The operator there on duty immediately telegraphs this number along four metallic "alarm" circuits, likewise diverging over the city, and communicating on their way with the church steeples, fire stations, signal-boxes, Victoria Barracks, (to summon the troops in cases of great emergency) the water-works, and police stations. Thus the time which elapses between the discovery of a fire by the inmates of a dwelling and its definite announcement by the church bells, gongs at fire stations, &c., and tappings in all the signal-boxes is, on an average, not more than a minute, and often much less. The firemen, with hose and ladders, start immediately to the actual scene of the fire, and no delay arises from uncertainty about its exact locality, as is so often the case in large English cities. In short, where this scheme is in operation, fire engines are never seen careering about the country in pursuit of an Aurora Borealis, (instances of which are not unfrequent in England) and a fire is almost invariably confined to the house where it originates, to which rule there were, for example, only two exceptions out of 121 fires which occurred in Montreal during the last year, 1865.

The idea of this system of signals, referred to a central point in case of fire, and thence resulting in instantaneous, universal, and definite alarms, originated with a Dr. Channing, of Boston, where it was first put into effect in April, 1852, and met with perfect success. Its working, it will be observed, is analagous to that of the nervous system in the human frame. The *signal boxes* distributed all over the city correspond with the nervous ganglions in a man's body; the *signal circuits* with the sensory nerves, by means of which external impressions are conveyed to the brain, (or *central office*) whence the motor nerves, corresponding with the *alarm circuits*, transmit certain required impulses to the necessary points.

On a similar system of centralization, a fire-alarm telegraph scheme was jointly devised by Dr. Channing and Mr. Farmer; and, as above stated, first came into operation at Boston in the year 1852. Its success so completely refuted the objections of its early opponents that the example of Boston was speedily followed by Baltimore, Charleston, Chicago, Cincinnati, Cleveland, New Orleans, New York, Philadelphia, St. Louis, Washington, and, indeed, most cities of importance in the United States. A curious contrast with it was the system of

fire-signalling previously in operation at New York, and thus described by Captain Basil Hall, R.N., who visited America forty years ago:—"On the top of the City Hall, one of the finest of the numerous public buildings which adorn New York, a fire-warden or watchman is constantly stationed, whose duty, when the alarm is given, is to hoist a lantern at the extremity of a long arm attached to the steeple, and to direct it towards the fire, as a sort of beacon to instruct the engines what course to steer. There was something singularly striking in this contrivance, which looked as if a great giant, with a blood-red finger, had been posted in the midst of the city to warn the citizens of their danger." And Sir Charles Lyell, who visited America in 1841, thus writes concerning the frequency of fire alarms at Philadelphia before the introduction of the present system of telegraphic signalling:—"We were five days in Philadelphia, and every night there was an alarm of fire, usually a false one; but the noise of the firemen was tremendous. At the head of the procession came a runner blowing a horn with a deep unearthly sound; next, a long team of men (for no horses are employed) drawing a strong rope to which the ponderous engine was attached, with a large bell at the top, ringing all the way; next followed a mob, some with torches, others shouting loudly, and before they were half out of hearing, another engine followed with a like escort; the whole affair resembling a scene in *Der Freischutz* or *Robert le Diable*, rather than an act in real life. It is, however, no sham, for these young men are ready to risk their lives in extinguishing a fire; and, as an apology for their disturbing the peace of the city when there was no cause, we were told 'that the youth here require excitement.'"

On the 8th July, 1852, there broke out in Montreal the most disastrous* fire ever known to have occurred in any city of Canada. It raged for twenty-six hours, destroyed 1,200 houses of various classes (valued at £500,000), and dislodged some 20,000 persons, whose homeless state was the more miserable in that it occurred during a hot season, when the thermometer showed a temperature of 95° to 100° in the shade. Such an event, as might be supposed, caused much attention to be paid to the various municipal arrangements affecting the general working of the fire department.† It was affirmed that, during the preceding seven years, more than one-half of the city had been laid in ashes; and it consequently occurred to the Corporation of Montreal that it would be desirable to adopt some measures which would prevent the recurrence of such calamitous accidents. A bye-law was accordingly passed to prohibit the construction of wooden buildings and shingled roofs within the boundaries of the city (enclosing an area of about 3,500 acres); but not till the year 1862 did the Town Council adopt the recommendation of their chief fire-engineer, and sanction the introduction of a fire-alarm telegraph scheme on the same principles

* Owing to the number of sufferers, and the loss of property, occasioned by the calamity. In Quebec, two fires, which occurred (with only one month's interval) in the year 1845, exceeded in combined extent and effect, the above-mentioned instance at Montreal. One fire, which destroyed 1650 houses, and rendered 12,000 persons homeless, occurred at Quebec on the 28th of May, 1845, and another, which destroyed upwards of 1,200 dwellings in less than 8 hours, and left 15,000 people without shelter, took place on the 28th of June in the same year.

† An account of this great fire is given in the Memoirs of Major Ranken, R.E., entitled "Canada and the Crimea." Amongst other reasons for its extent, he mentions (page 26) that the city reservoir being nearly empty at the time, scarcely any water was available for the purpose of checking the flames.

as that which had, ten years before, proved so signally successful at Boston. This system first came into operation at Montreal in January, 1863, having been constructed by Messrs. J. F. Kennard and Co., of Cincinnati, (who have taken out sixteen patents in America, in connection with the apparatus) at a total cost of £4,110. Its average annual expense is £3,700; this sum including the salaries of all officers and men of the fire and telegraph departments, the clothing of firemen, purchase of horses, forage, repairs to apparatus, printing, insurance, &c., beside the incidental expense of building-inspector, and of street-watering during the summer months. Profiting by the ten years' experience of other cities, and embodying the latest improvements, the Alarm-Telegraph system of the Montreal Fire Department has been organized in so efficient a manner that it is now considered the model establishment of the kind on this Continent. Several European cities, it is said, are meditating the adoption of the same scheme, whereby a large amount of property may be annually saved, and the loss of many lives prevented. Whether or no this be true, it is admirably suited—it is almost essential—to the preservation of large American and Canadian towns, which are particularly liable, during the long winter months, to devastation by the destructive element, owing to the frequent occurrence of fires produced by an excessive consumption of fuel and the employment of stoves in ill-constructed houses.

A few words may be now said concerning the details of the apparatus, &c., in actual use at Montreal at the present time. The circuit lines (varying in length from $3\frac{1}{2}$ to 5 miles) consist of No. 9 galvanized iron-wire suspended by glass insulators, which rest in wooden brackets attached to poles 30 or 40 feet high. The poles are placed at intervals of about 70 yards; they are 10 in. or 12 in. in diameter at bottom, and taper to about half that size at top. Both "signal" and "alarm" circuits are completely metallic, but those of the waterworks and police departments are (like those of ordinary despatch lines) completed by the earth. The latter of these—quite unconnected with the fire-telegraph—serve as the means of rapid communication between the chief of police and his subordinates in the different stations about the city. Its every-day uses are manifest, and, in case of riot or any public disturbance, it enables the mayor, or chief of police, to dispose of the force to the best advantage in the shortest possible time. This telegraph is furnished with Siemen's dial instruments, which are so simple in their operation that any person of ordinary intelligence can use them without previous instruction. All the apparatus connected with it is placed in charge of the fire-department operators, who are clearly best fitted for the duty, from their acquaintance with electric instruments. The ground line below each signal-box (to be used only in case of accident) is made to terminate in some conducting channel, such as a spring of water, a drain, a gas-pipe, or a metal plate (zinc or lead) buried six or eight feet below the surface of the ground; and, as the electric current is always passing over the signal circuits, a break at any point instantaneously reports itself at the head-quarters by the running of the "register," and the ringing of a bell.

The species of battery employed in connection with these telegraphic lines is a modified form of Daniel's, but more uniform in action, and *minus* the porous earthenware cup. Each battery consists of twenty-five cells, and each cell of a circular glass jar 8 in. high and 7 in. in diameter. Round the inside of the jar, at

its bottom, is folded a strip of sheet copper 3 in. wide, to which is attached an insulated copper wire projecting out of the jar, as shown in Pl. II. fig. 1. From 2 to 3 lbs. of dry crystals of sulphate of copper are then added, and a cone of zinc (3 in. high, and of the same diameter at the base as the glass vessel) is suspended, apex downwards, from the mouth of the jar. Through a hole in this zinc there is poured a dilute solution of sulphate of zinc; and thus, from the different specific gravities of the two sulphates, the copper always remains immersed in a solution of sulphate of copper, and the zinc in a solution of sulphate of zinc. A copper wire (No. 14) from the zinc, connects, in an ordinary screw cup, with the insulated copper wire of the adjoining cell, and the battery is complete, its action continuing until the solution becomes saturated with the sulphate of zinc. It was shewn to me by the chief telegraph-operator, Mr. Badger, as his own idea, and he stated that it was first used in the beginning of the year 1865. Nor did he know that the principle had been put into effect in any other part of the world, until I produced a copy of the lecture by Captain Schaw, R.E., on "The Employment of Electricity in Military Operations," delivered at the Royal United Service Institution, on the 24th February, 1865, wherein a similar species of battery to that above described is mentioned as being in use at the telegraphic schools of the Royal Engineer Establishment, at Chatham; but in the "Schaw" battery which was perfected in 1862, the zincs are simple parallelopipedons, and the battery is charged by putting in dry crystals of sulphate of copper, and then filling up with water. However, the Montreal Fire-Alarm Telegraph battery has been described in this paper so fully, as I ascertained that its inventor had, in truth, been experimenting on the subject for some time previous to its adoption; and it thus forms one of the many curious instances of discoveries being independently made at about the same time by different persons.

The "signal-boxes" of the Fire-Alarm Telegraph are attached to the sides of houses or to the posts for telegraph wires, at a height of about 5 feet from the ground. They are made of half-inch cast-iron, and are cottage shaped, 1 ft. 8 in. high, 1 ft. 1 in. wide, and 6 in. deep. A sign overhead tells where, in the immediate vicinity, the key may be found. Keys are also supplied to all the policemen, and though a few have gone astray into the possession of certain frolicsome individuals who occasionally indulge in the cheerful joke of raising a false alarm, yet such accidents are of rare occurrence, and have been a good deal discouraged of late by some interviews that have taken place between the interested parties, on which occasion the infuriated firemen have invariably got the best of the argument. Figs. 2 and 3, Pl. II, represent respectively a closed and an open "signal-box." By turning the crank shewn in the latter, a small brass wheel, upon the same axle, is made to revolve likewise; and each revolution signalizes the number of the box at the central telegraph office. For, on the wheel's circumference, there are studs or projections, varying with the number of each box, so as to correspond with the peculiar combination of dots and dashes used in Bain's system of notation, whereby (in the central office) this number can be indicated upon a strip of paper by the "pen-marker" of Morse's recording instrument. Thus, each revolution of the wheel causes all its projections, in due order, to depress a little horizontal brass lever placed immediately beneath it, to which a spring is attached, so that it at once resumes its position after each projection has passed. At the end of this lever, and at right angles

to it, is attached a brass connecting-slide, resting upon two brass connecting-plates, in which the wires of the signal circuit-terminate. Consequently the depression of the lever throws the connecting-slide off the plates, and breaks the circuit, until the wheel's projection be passed—a point on its circumference forming a dot on the strip of paper in the recording instrument, and a longer projection forming a dash. Repeated turns give repetitions of the same signal; it is scarcely necessary to remark that it is transmitted by the intervention of a "relay" battery, and that the announcement of the "signal-box" number, on turning the crank, is always preceded by the ringing of a "call," or office alarum bell, to attract the attention of the operator on duty. He then—by simply moving to the proper number the "tens" and "units" hands upon the two dials of the "striker," or "repeater" (which consists of a cylinder moved by clockwork, upon whose circumference are metal plates connected with the several alarm-circuits)—throws all the striking instruments of the city into simultaneous action, and thus gives instantaneous public alarm; that is to say, the number of the box whence the alarm proceeded is synchronously struck by the bells in the church-towers, the gongs in the engine-houses, and the signal-boxes throughout the city. Each signal-box is provided with a "lightning-arrester" and an electro-magnet, for communication with the central office. (In Fig. 2, to avoid confusion, the wires are not shewn in connection with the electro-magnets).

Four bell-towers, viz., those of the English Cathedral, the French Cathedral, St. George's Church, and St. James's Church, sound this public alarm by means of a striking machine, wielding a hammer which is released by an electro-magnet, the number and frequency of the blows being governed by the "repeater" at the central office.

In tolling out the box number, the bells first sound the tens, and then after a pause of five seconds, the unit; half-a-minute is allowed to elapse before the alarm is again sounded. If it be considered advisable to alarm only a part of the city, the operator can, by means of "switches," disconnect one or more of the alarm circuits from the "repeater," and the bells upon those circuits are silent. Three alarms of the signal-box number turn out the nearest section of the fire brigade, who proceed at once to the locality specified. Should more assistance be required, two additional alarms summon the second section, whilst the third (making up the entire force) proceeds likewise to the fire on a single alarm being sounded after the two preceding warnings.

The mode of tripping the heavy church-bell hammers, by Farmer's electro-magnetic escapement, is very ingenious. In this escapement, the electro-magnet in the church-tower, on the electric "alarm-circuit," being completed at the central telegraph office, attracts its soft iron armature, which supports a small lever poised nearly vertically, and weighted with a little ball at its upper end. This lever and ball, when tripped by the withdrawal of the armature, acquire sufficient momentum to strike up the detent of a ratchet-wheel (relieving the strain of 1,000 lbs. weight), which wheel, in its revolution, works two levers, first raising the hammer and then allowing it to fall against the bell. The revolution of the train of wheels raises also the falling lever into its place, and catches it again on the armature lever, ready to be disengaged, or tripped, for another blow, by the electric impulse communicated at will from the central telegraph office.

The *personnel* of this office consists of a chief operator and two assistants, who take up duty in turn for four hours at a time. The operator on duty has, as a proof of his constant attendance and vigilance, to test the batteries and adjust the apparatus every twenty minutes, this act being recorded by a pencil moved by an electro-magnet, upon a dial indicating the hour, but enclosed in a case out of his reach. The operators have likewise to examine and test all the signal-boxes at least once a week.

A noticeable feature of the present Montreal Fire Department, noticeable at least in this country*, is the employment of a permanent and paid fire brigade, instead of a corps of volunteer firemen, as under the old American system, and as at present constituted at Quebec, where the fire companies clothe themselves gorgeously, rejoice in the titles of "Sapeurs," "Sapeurs Voltigeurs," "Brigade Navale," "Dragons," &c., and are wont to parade the streets, on festive occasions, in much solemnity and gold lace. But imposing as is their appearance, efficient as they may be, and popular as is the service (for the service must always be popular which offers to men such opportunities for personal distinction†) it is evidently better to adhere to the old principle of a division of labour, and to rely, for the performance of special public duties, upon a body of men specially trained and paid to perform them. The economy and greater efficiency of the existing system will be best understood from the following tabular comparison of two successive years, selected at hap-hazard, under the old and new *régime* respectively, in Montreal:—

Year.	Number of Fires.	Loss of Property.	Cost of the entire Fire Department.
1855	57	54,110 dollars	18,098 dollars.
1856	85	140,088 „	19,144 „
1864	99	35,428 „	19,116 „
1865	121	52,299 „	17,877 „

[The pound sterling, be it remarked, is very nearly equal to 4 dollars 87 c.]

The length of the foregoing details may possibly convey an impression prejudicial to the simplicity of the system I have endeavoured to describe, yet such an impression will, on close examination, be found to be groundless, the ease and perfection of the working of the system being amongst its chief characteristics. And its economy is another point which recommends it to favour, for no means of providing against danger should be unwisely neglected, and the expense bears but a small proportion to the security provided; it is surely insignificant, in comparison with the protection afforded to a populous city against one of the most fearful calamities to which it can be exposed.

* "Probably no change in any municipal department of the City of New York has been attended with so much discussion as the establishing of a paid Fire Department in the metropolis. After the display of considerable legal acumen, the Court of Appeal finally decided that the act of the Legislature creating the department was constitutional."

American Paper (Frank Leslie's) 26th August, 1865.

† Thus Kinglake's description of the glory-craving Marshal St. Arnaud: "If for instance there chanced to be a fire at night, he would fly to the spot, would scale the ladders, mount the roof, and contrive to appear aloft in seeming peril, displayed to a wondering crowd by the lurid glare of the flames. Then he would disappear, and then suddenly he would be seen again suspended in the air, and passing athwart the sky that divided one roof from another, by the help of a rope or a pole."

"*Invasion of the Crimea*," Vol. II, Chap. I.

And it will be remembered that one of the very first volunteer regiments which left New York, in April, 1861, consisted of Ellsworth's "Fire Zouaves."

Should it ever be adopted in Europe, several improvements might be introduced. It might, for example, be thought desirable to attach the different circuit wires to poles resting upon the roofs of houses (instead of detached supports) so as to preclude the possibility of their being meddled with. It might also be thought expedient to restrict the announcement of a fire-alarm to the engine-houses, or the fire and police stations, instead of clanging it forth from all the church towers. For, in London, or any large city, it seems by no means wise to inform the general public of the exact whereabouts of a fire—a species of entertainment which the populace are apt to attend in large numbers, with much misdirected zeal, and a strong propensity for impeding, in an amateur capacity, the legitimate labours of the regular fire brigade.

A municipal telegraph is susceptible of many uses besides that of merely giving the fire alarms. I have already mentioned the police telegraph at Montreal, which affords the chief of police such control over the entire department, that he can issue instructions to every man of the force within a minute, should their services be required instantaneously, as for the detection of a criminal or the suppression of a riot. The calling to arms of the city volunteers—performed by a certain recognized number of blows from the church bells—forms a third use of the telegraph; and, fourthly, it gives uniform time to the city each day, at the exact moment of noon, (telegraphed from the McGill College Observatory) by simultaneously striking all the church bells, and lowering a large time-ball provided for the purpose by the Harbour Commissioners.

But it comes not within the province of this paper to deal at length with more than the Fire-Alarm Telegraph of Montreal, which (however imperfectly described in this paper) has been so admirably organized and carried into execution, and which contributes so materially to the security of the city, that it forms now an "institution" of which Montreal does well to be proud.

G. E. G.

Royal Engineer Camp,
Point Jervis, Quebec,
June, 1866.

PAPER VII.

ON RECENT PROGRESS IN THE HISTORY OF PROPOSED SUBSTITUTES FOR GUNPOWDER.*

BY PROFESSOR F. A. ABEL, F.R.S., V.P.C.S.,
CHEMIST TO THE WAR DEPARTMENT.

The changes which have been effected in the composition of gunpowder, since its first application as a propelling agent, have been limited to small variations in the proportions of its constituents. But the modifications which have from time to time been introduced into the details of its manufacture, *e.g.* the preparation of the ingredients, their incorporation, and the conversion of the mixture into compact masses (grains, &c.) of different size and density, have been sufficiently important and successful to secure the fulfilment by gunpowder, in a more or less efficient manner, of the very various requirements of military science and of different branches of industry.

The characteristics of gunpowder, as an explosive material of permanent character, the action of which is susceptible of great modification, are mainly ascribable to the peculiar properties of the oxidizing agent, saltpetre. Frequent attempts have been made to replace this constituent of gunpowder by other nitrates (such as those of sodium, lead, and barium); but, although materials suitable for blasting operations have been thus prepared (such as soda-gunpowder, and barytic powder, or *poudre saxifragine*), all mixtures of this class, hitherto produced, have exhibited important defects, when compared with gunpowder manufactured for propelling purposes.

The well-known oxidising agent, chlorate of potash, which differs from saltpetre only in containing chlorine in the place of nitrogen, is far more energetic in its action upon oxidizable bodies than any of the nitrates. Thus, a mixture of chlorate of potash with charcoal alone, deflagrates as violently as gunpowder, and is far more readily inflamed by percussion than the latter; while a mixture analogous to gunpowder, containing chlorate of potash in place of saltpetre, detonates violently when struck with moderate force, and acts far too destructively, on account of the rapidity of its explosion, to admit of its safe employment in fire-arms.

* A Paper read at the Royal Institution on the 4th of May, 1866, and now reprinted by permission of the Author.

Many years ago, a mixture known as German or white gunpowder, and consisting of chlorate of potash, ferrocyanide of potassium, and sugar, was proposed and tried without success as a substitute for gunpowder; and since then many preparations of similar character have been suggested for employment either as blasting and mining agents, or for use in shells, or even for all the purposes to which gunpowder is applied. The most promising of these, claimed as discoveries by Mr. Horsley and Dr. Ehrhardt, are mixtures of chlorate of potash with substances of permanent character and readily obtained, containing both carbon and hydrogen; such as tannic and gallic acids, and some kinds of resins. These mixtures are much less violently detonating than most of the explosive mixtures containing chlorate of potash, while, if well prepared, they are decidedly more powerful, as explosives, than gunpowder. For blasting purposes, some of these mixtures probably possess decided advantages over ordinary blasting powder, and possibly they may also be susceptible of employment for sporting purposes; but they are not applicable to fire-arms used for war purposes, because, in order to ensure the requisite uniformity of action, the ingredients must be submitted to proper processes of incorporation, &c., such as are applied to the manufacture of gunpowder; and this treatment would render the mixtures far more violent, and consequently destructive in their action upon fire-arms, than if used in the form of crude mixtures.

A comparatively very safe application of chlorate of potash to the production of a substitute for gunpowder, was made about six years ago by a German chemical manufacturer, M. Hochstädter. Unsized (blotting) paper was thoroughly soaked in, and coated with, a thin paste consisting of chlorate of potash, finely-divided charcoal, a small quantity of sulphide of antimony, and a little starch, gum, or some similar binding material, water being used as the solvent and mixing agent. The paper was rolled up very compactly and dried in that form. In this manner, very firm rolls of an explosive material are obtained, which burns with considerable violence in the open air, and the propelling effect of which, in small arms, has occasionally been found greater than that of a corresponding charge of rifle powder. Moreover, the material, if submitted in small portions to violent percussion, exhibits but little tendency to detonation. But as no reliance can be placed on a sufficient uniformity of action, in a fire-arm, of these explosive rolls, this alone suffices to prevent their competing with powder. The same description of explosive preparation, differing only from that of M. Hochstädter in a trifling modification of its composition, which is certainly not likely to lead to its greater success, has recently been brought forward in this country by M. Reichen and Mr. Melland.

One or two other much cruder explosive preparations, containing chlorate of potash, alone or in conjunction with saltpetre, have met with some application to blasting purposes. One of these consisted of spent tan, in small fragments, which was saturated with the oxidising agent, and afterwards dusted over with sulphur. When flame or a red-hot iron is applied to this preparation, it deflagrates very slowly and imperfectly; but when employed in blast-holes, where it is confined within a small space, it developes sufficient explosive force to do good work. In addition to comparative cheapness, the great advantage of safety was claimed for this material by its inventor, a claim which was substantiated

the partial destruction by fire, on two occasions, of a manufactory of the substance near Plymouth, without the occurrence of an explosion.

The accidental explosions of gunpowder which are occasionally heard of, occur, in most instances, at the manufactories, and in the course of some operation (especially that of incorporation) to which the explosive mixture is submitted. The only means of guarding against, or reducing as much as possible, the liability to the occurrence of these accidents, consist in the strictest attention to the precautionary measures and regulations, which experience has proved to be essential to safety, and which, in spite of the strictest supervision, are unquestionably sometimes overlooked or imperfectly carried out by workmen. Explosions of gunpowder, generally of a serious character, do occur, however, though very rarely, during the transport of the material, or in the magazines where it is stored. The great explosion of a gunpowder magazine at Erith in September, 1864, specially directed the attention of government and the public generally, to the necessity of adopting measures for reducing, as much as possible, the risk of occurrence of such disastrous accidents. Hence, much interest has recently been excited by a well-known method of rendering gunpowder less dangerous in its character, which has been brought prominently before the public by Mr. Gale, and which consists of diluting powder, or separating its grains from each other, by means of a finely powdered non-explosive substance. Attempts have several times been made in past years, to apply to practical purposes the obvious fact, of which nobody acquainted with the nature of gunpowder could be ignorant, that, by interposing between the grains of powder a sufficient quantity of a finely divided material, which offers great resistance to the transmission of heat, the ignition of separate grains of the entire mass may be accomplished without risk of inflaming contiguous grains. In 1835, Piobert made a series of experiments with the view to apply this fact practically, to reduce the explosiveness of gunpowder, and similar experiments of an extensive character were carried on by a Russian chemist, Fadéiff, between 1841 and 1844. These experimenters found that the object in view might be attained by diluting gunpowder with any one of its components; they also employed very fine sand (a substance closely allied in its physical characters to the powdered glass, which Mr. Gale now proposes to use); but the preference appears to have been given to a particular form of carbon. It was not attempted altogether to prevent the burning of a mass of gunpowder, when a spark or flame reached any portion, but to reduce the rapidity of combustion so greatly as to prevent the occurrence of a violent explosion. No more than this is accomplished by the employment of powdered glass in the proportions directed by Mr. Gale. Indeed, as the quantity of diluent required to give to different kinds of gunpowder the character of equally slow-burning materials, increases with the explosiveness of the particular powder and with the size of its grain, the proportion of powdered glass with which the gunpowder employed in rifled cannon would have to be mixed to render it only slow-burning, would be about double the quantity required for almost altogether preventing the ignition of fine-grain powder, or of the comparatively weak blasting powder with which Mr. Gale's public experiments appear generally to have been instituted. Although a sufficient dilution of gunpowder may secure such comparative safety to the neighbour-

hoods of large magazines, or to the crews of merchant vessels in which gunpowder (for blasting purposes, &c.) is transported, as to compensate fully for the inconvenience attending the great increase of volume of the powder, there is no doubt that such a treatment of gunpowder actually issued for military and naval service would be attended by more than one serious obstacle; such as, the tendency of the powder, unless very largely diluted, to separate from the glass, during transport by land or sea, to so considerable an extent as very greatly to diminish the degree of security originally aimed at; the very great addition which would have to be made to the arrangements for carrying the necessary ammunition, in active service; the necessity for introducing, in the field or on board ship, the operations of separating the powder from the glass and transferring it to cartridges and shells (which, whatever sifting and other arrangements were adopted, would be time-taking and very dangerous), instead of preserving the ammunition ready for immediate use; and, above all, the incalculable mischief which would inevitably result from the establishment, in the minds of the soldier and sailor, of an erroneous feeling of security, in dealing with gunpowder, which, however harmless it may, for a time, be rendered, must finally be handled by the men in its explosive form. The extremely rare occurrence of accidents with gunpowder, on board ship or in active land-service, is mainly due to the strictest enforcement of precautionary regulations, some of which may appear at first sight exaggerated or almost absurd, but which combine to maintain a consciousness of danger and a consequent vigilance indispensable to safety.

One of the most remarkable materials recently employed to replace gunpowder as a destructive agent, is nitro-glycerine. This substance was discovered by *Sobrero*, in 1847, and is produced by adding glycerine in successive small quantities to a mixture of one volume of nitric acid of sp. gr. 1·43, and two volumes of sulphuric acid of sp. gr. 1·83. The acid is cooled artificially during the addition of the glycerine, and the mixture is afterwards poured into water, when an amber-coloured oily fluid separates which is insoluble in water, and possesses no odour, but has a sweet, pungent flavour, and is very poisonous, a minute quantity placed upon the tongue producing violent headache, which lasts for several hours.

The liquid has a specific gravity of 1·6, and solidifies at about 5° C. (41° F.); if flame is applied, nitro-glycerine simply burns; and if placed upon paper or metal, and held over a source of heat, it explodes feebly after a short time, burning with a smoky flame. If paper moistened with it be sharply struck, a somewhat violent detonation is produced. Alfred Nobel, a Swedish engineer, was the first to attempt the application of nitro-glycerine as an explosive agent, in 1864.

Some experiments were, in the first instance, made with gunpowder, the grains of which had been saturated with nitro-glycerine. This powder burnt much as usual, but with a brighter flame, in open air. When confined in shells or blast-holes, greater effects were, however, produced with it than with ordinary gunpowder; its destructive action is described as having been from three to six times greater than that of powder. The liquid could not be employed as a blasting agent in the ordinary manner, as the application of flame to it from a common fuze would not cause it to explode. But Mr. Nobel has succeeded, by

employing a special description of fuze, in applying the liquid alone as a very powerful destructive agent. The charge of nitro-glycerine having been introduced, in a suitable case, into the blast-hole, a fuze, to the extremity of which is attached a small charge of gunpowder, is fixed immediately over the liquid. The concussion produced by the exploding powder, upon ignition of the fuze, effects the explosion of the nitro-glycerine.

The destructive action of this material is estimated, by those who have made experiments in Sweden and Germany, as about ten times that of an equal weight of gunpowder. Therefore, although its cost is about seven times that of blasting-powder, its use is stated to be attended with great economy, more especially in hard rocks, a considerable saving being effected by its means in the labour of the miners, and in the time occupied in performing a given amount of work, as much fewer and smaller blast-holes are required than when gunpowder is employed. The material appears to have recently received considerable application in some parts of Germany and in Sweden; but, in England, its employment has been confined to one set of experiments instituted in Cornwall last summer, upon which occasion a wrought-iron block, weighing about three hundredweight, was rent into fragments by the explosion of a charge of less than one ounce of nitro-glycerine placed in a central cavity.

Nitro-glycerine appears, therefore, to possess very important advantages over gunpowder as a blasting and destructive agent, but the attempts to introduce it as a substitute for gunpowder have already been attended by most disastrous results, ascribable in part to some of its properties and the evident instability of the commercial product, but principally to the thoughtlessness of those interested in its application, who appear to have been induced, either by undue confidence in its permanence and comparative safety, or from less excusable motives, to leave the masters of ships, or others who had to deal with the transport of the material, in ignorance of its dangerous character.

The precise causes of the fearful explosions of nitro-glycerine which occurred at Aspinwall and San Francisco, will, in all probability, never be ascertained; but they are likely to have been due, at any rate indirectly, to the spontaneous decomposition of the substance, induced or accelerated by the elevated temperature of the atmosphere in those parts of the ships where it was stored. Instances are on record in which the violent rupture of closed vessels containing commercial nitro-glycerine has been occasioned by the accumulation of gases generated by its gradual decomposition; and it is at any rate not improbable that a similar result, favoured by the warmth of the atmosphere, and eventually determined by some accidental agitation of the contents of the package of nitro-glycerine, was the cause of those lamentable accidents. The great difficulties attending the purification of nitro-glycerine upon a practical scale, and the uncertainty, as regards stability, of the material, even when purified (leaving out of consideration its very poisonous character and its extreme sensitiveness to explosion by percussion when in the solid form), appear to present insurmountable obstacles to its safe application as a substitute for gunpowder.

The conversion of purified lignin or wood-fibre into an explosive substance of the same nature as gun-cotton, was accomplished by chemists soon after Schönbein's discovery of gun-cotton was made known. Finely divided wood, or sawdust, may, by treatment with suitable agents, be to a very considerable extent

purified of substances foreign to cellulose; and if then submitted to careful digestion in a mixture of the strongest nitric and sulphuric acids, and properly purified, it furnishes a highly explosive material similar to the most explosive gun-cotton, and possessed apparently of considerable stability. Capt. Schultze, a Prussian artillery officer, who was entrusted by his government a few years ago with the investigation of gun-cotton, appears to have come to the conclusion that finely-divided wood offered greater prospect of conversion into a controllable explosive agent than cotton wool. The ultimate result of his investigations has been the production of a "gun-sawdust," the explosive properties of which depend in great measure upon its impregnation with a considerable proportion of an oxidizing agent, either saltpetre or a mixture of that salt and nitrate of baryta. The wood, having been reduced to a tolerably uniform state of division, is submitted by Captain Schultze to purifying processes, for the separation of resinous and other substances from the lignin, and the product is converted by digestion in a mixture of sulphuric and nitric acids into a very feebly explosive material, which leaves a considerable carbonaceous residue when burnt. This product, after purification, is impregnated with a sufficient proportion of nitrates to give it rapidly explosive power, the oxidation of the carbon being now almost complete. The objects which appear to be aimed at by Captain Schultze in following this method of manufacturing a wood-gunpowder, are, the production of a more gradually explosive material than is obtained by the most perfect action of nitric acid upon wood-fibre, and the possibility of preserving the material in a slightly explosive and therefore comparatively harmless form, until it is required for use, when it may be soon rendered powerfully explosive by impregnation with the nitrates. It is asserted that this powder is considerably more powerful than gunpowder as a mining agent; and that, by its employment in mines, the operators are enabled to return to work sooner than when gunpowder is used, because there is little or no smoke produced by its explosion. The latter is an undoubted advantage which Schultze's powder shares with gun-cotton. Advantages are also claimed for this material when employed in fire-arms, and it is possible that, when applied to sporting purposes, it may compete successfully with gunpowder in this direction also; but its behaviour as an explosive, and the peculiarities of its structure, afford little promise of its advantageous employment in arms for military and naval purposes.

Important progress has been made in the history and the practical application of gun-cotton since its study was resumed in this country about three years ago. Very considerable quantities of the material have been manufactured at the works of Messrs. Prentice, at Stowmarket, and at the Government gunpowder works, at Waltham Abbey; its application to mining and artillery purposes, and to small arms, has been, and is still, the subject of systematic experiment, conducted by the Government Committee on Gun-cotton; its employment as a blasting agent is steadily increasing in several important English mining districts; and considerable, though not uniform, success has already attended the employment of gun-cotton cartridges for sporting purposes.

The system of manufacture of gun-cotton, as perfected by Baron Von Lenk, has undergone but trifling modifications in its employment in this country. It has been made the subject of careful investigation by Mr. Abel, and the results

furnished by many experimental manufacturing operations, and an examination of the products, have shewn that the process of converting cotton into the most explosive form of pyroxilin or gun-cotton, and of purifying the material, has been so greatly perfected by Von Lenk as to render a strict adherence to his simple and precise instructions alone necessary to ensure the preparation of very uniform products, which exhibit in their composition a very much closer approximation to purity than those obtained in the earlier days of the history of gun-cotton.*

---

* Baron Von Lenk's process is described by Professor Abel in a lecture delivered at the United Service Institution, in October, 1864, in the following words:—"The cotton, in the form of loose yarn of different sizes, made up into hanks, is purified from certain foreign vegetable substances, by treatment for a brief period with a weak solution of potashes, and subsequent washing. It is then suspended in a well-ventilated hot-air chamber until all moisture has been expelled, when it is transferred to air-tight boxes or jars, and at once removed to the dipping tank, or vessel, where its saturation with the mixed sulphuric and nitric acids is effected. The acids, of the specific gravity prescribed by Schönbein, are very intimately mixed in a suitable apparatus, in the proportions originally indicated by that chemist, *i.e.*, three parts by weight of sulphuric acid to one of nitric acid. I should explain that sulphuric acid is not used for the purpose of exerting any chemical action upon the cotton, but merely for promoting the action of the nitric acid. Strong sulphuric acid or oil of vitriol has a remarkable tendency to combine with water, and this property is usefully applied in the manufacture of gun-cotton, for the purpose of abstracting water, which the nitric acid contains, and thus rendering the latter more concentrated, and also for preventing the water, which, as you know, is produced in the chemical change, from interfering with the action of the nitric acid upon the cotton.

"The mixture of acids is always prepared some time before it is required, in order that it may become perfectly cool. The thoroughly dry cotton is immersed in a bath of the mixed acids, one skein at a time, and stirred about for a few minutes until it has become thoroughly saturated with the acids; it is then transferred to a shelf in this dipping trough, where it is allowed to drain, and slightly pressed, to remove any large excess of acid; and is afterwards placed in an earthenware jar, provided with a tightly fitting lid, which receives six or eight skeins, weighing from two to four ounces each. The cotton is tightly pressed down in the jar, and if there be not sufficient acid present just to cover the mass, a little more is added; the proportion of acid to be left in contact with the cotton being about 10½ pounds to one pound of the latter. The charged jars are set aside for 48 hours in a cool place, where, moreover, they are kept surrounded by water to prevent the occurrence of any elevation of temperature, and consequent destructive action of the acids upon the gun-cotton. The same precaution is also taken with the dipping-trough, as considerable heat is generated during the first saturation of the cotton with the acids. At the expiration of 48 hours, the gun-cotton is transferred from the jars to a centrifugal machine, by the aid of which the excess of acid is removed as perfectly as is possible by mechanical means, the gun-cotton being afterwards only

Although the conclusions arrived at by the many chemists who investigated the composition of gun-cotton, soon after Schönbein's discovery, varied very considerably, the constitution has been very generally regarded as definitely established by the researches of Hadow, published in 1854. According to that chemist, the most explosive gun-cotton has the composition expressed by the formula $C_6\ H_7\ N_3\ O_{11}$ (which was first assigned to the substance by W. Crum, in 1847), and may be regarded as cellulose, in which three atoms of hydrogen are replaced by three molecules of peroxide of nitrogen. The name *trinitro-cellulose* has therefore been assigned to gun-cotton, its constitution being expressed by the formula $C_6 \left\{ \begin{matrix} H_7 \\ 3\ N\ O_2 \end{matrix} \right\} O_5$. Hadow's conclusions have since been confirmed by other chemists, more especially by Redtenbacher, Schrötter, and Schneider who have analized specimens of gun-cotton prepared under Von Lenk's directions. But a report upon the Austrian Gun-cotton was published in 1864 by Pelouze and Maury, in which the formula $C_{24}\ H_{36}\ O_{18},\ 5\ N_2\ O_5$ is assigned to the product of Von Lenk's process; the conclusions of those chemists being founded partly upon some analytical results, and partly upon the increase of weight which they found cotton to sustain, when submitted to treatment with the mixed acids. They found the greatest increase in weight to be 78 per cent.—a number slightly in excess of that which would correspond to the requirements of the formula which they adopt.

---

slightly moist to the touch. The skeins are then immersed singly in water, and moved about briskly, so as to become completely saturated with it as quickly as possible. This result is best accomplished by plunging the skeins under a fall of water, so that they become at once thoroughly drenched. If they were simply thrown into water and allowed to remain at rest, the heat produced by the union of a portion of the free acids with a little water would be so great as to establish at once a destructive action upon the gun-cotton by the acid present. The washing of the separate skeins is continued until no acidity can be detected in them by the taste; they are then arranged in frames or crates and immersed in a rapid stream of water, where they remain undisturbed for two or three weeks. They are afterwards washed by hand, to free them from mechanical impurities derived from the stream, and are immersed for a short time in a dilute boiling solution of potashes. After this treatment they are returned to the stream, where they again remain for several days. Upon their removal they are once more washed by hand, with soap if necessary; the pure gun-cotton then only requires drying to render it ready for use. A supplementary process is, however, adopted by General Von Lenk, about the possible advantage or use of which his opinion is not shared by others, as already stated. This treatment consists in immersing the air-dried gun-cotton in a moderately strong hot solution of soluble glass (silicate of potassa or soda), for a sufficient period to allow it to become completely impregnated; removing the excess of liquid by means of the centrifugal machine; thoroughly drying the gun-cotton, thus 'silicated,' and finally washing it once more for some time, until all alkali is abstracted. Lenk considers that, by this treatment, some silica becomes deposited within the fibre of the gun-cotton, which, on the one hand, assists in moderating the rapidity with which the material burns, and, on the other hand,

An experimental inquiry into the composition of gun cotton, as obtained by Von Lenk's process, has been instituted by Mr. Abel; and the very numerous analytical and synthetical results which he has obtained, confirm the correctness of the formula assigned by Crum and Hadow to the most explosive gun-cotton, and demonstrate satisfactorily that the products obtained by following strictly the instructions given by Von Lenk, are invariably trinitro-cellulose, in a condition as nearly approaching purity as a manufacturing operation can be expected to furnish.

The most explosive gun-cotton is perfectly insoluble in mixtures of ether and alcohol; but by varying the proportions and strength of the acids employed for the conversion of cotton, products of less explosive character are obtained, which are more or less freely soluble in ether and alcohol (furnishing the well-known material *collodion*). If, therefore, in manufacturing gun-cotton, the conditions essential to the production of insoluble pyroxilin are not strictly fulfilled, the uniformity of the product will suffer.

The ordinary products of manufacture are never altogether free from soluble gun-cotton; but the proportion present is small and very uniform, amounting to about 1·5 per cent. They contain, besides, a small quantity (about 0·5 per cent.) of matter soluble in alcohol alone, and possessed of acid characters, which is evidently produced by the action of nitric acid upon such small quantities of

---

exercises (in some not very evident manner) a preservative effect upon the gun-cotton, rendering it less prone to undergo even slight changes by keeping. The mineral matter contained in pure gun-cotton which has not been submitted to this particular treatment amounts to about one per cent. The proportion found in specimens which have been 'silicated' in Austria and in this country, according to Lenk's directions, varies between 1·5 and 2 per cent. It is difficult to understand how the addition of one per cent. to the mineral matter, in the form chiefly of silicates of lime and magnesia (the bases being derived from the water used in the final washing), which are deposited upon and between the fibres in a pulverulent form, can influence, to any material extent, either the rate of combustion or the keeping qualities of the product obtained by Lenk's system of manufacture.

"The gun-cotton, when thus prepared, is carefully dried and stored in well ventilated rooms, heated to about 80° Fahrenheit. This is the only operation where there is any possibility of danger. The manufacture of this material possesses most important advantages over that of gunpowder. In the manufacture of the latter, the operations are all of a dangerous character, from the moment the materials are mixed up to the final drying process; while this is the case with gunpowder, the processes to which cotton-wool is submitted for conversion into pure gun-cotton are all harmless; and it is only when it reaches the drying process that any risk of accident can occur. But if this drying process be conducted with care, the temperature of the room being carefully regulated, there is really no actual danger, even in this operation. It merely requires attention to the precautions ordinarily used in the manufacture of gunpowder, such as the exclusion of possible sources of fire, to ensure the safety of the drying process."

resinous or other matters foreign to pure cellulose, as are not completely removed from the cotton fibre by the purification which it receives.

There appears good reason to believe that this impurity in gun-cotton is of comparatively unstable character, and that the great proneness to spontaneous decomposition which has been observed by Pélouze and Maury, De Luca, and others, in some specimens of gun-cotton, is to be ascribed in great measure to the existence in those specimens of comparatively large proportions of those unstable bye-products.

One hundred parts of carefully-purified cotton wool have been found by Mr. Abel to furnish from 181·8 to 182·5 parts of gun-cotton. The increase which *perfectly pure cellulose* should sustain by absolutely complete conversion into a substance of the formula $C_6 H_7 N_3 O_{11}$ *(trinitro-cellulose)* is 83·3: the above results are therefore strong confirmations of the correctness of this generally-accepted view of the composition of gun-cotton. In carrying out the actual manufacturing process, as prescribed by Von Lenk, somewhat lower results are obtained, because of impurities existing in the cotton employed, and of loss of product during its purification.

Very extensive experiments are in progress at Woolwich, with the view of examining fully into the extent of liability to change of gun-cotton when preserved in store, or exposed for prolonged periods to light and to degrees of heat ranging between the ordinary atmospheric temperatures and that of boiling water. The results hitherto arrived at, though they have shown that, under severe conditions, gun-cotton is liable to decompose, have not confirmed the conclusions arrived at by the French chemists, with regard to the great instability of the material. Thus De Luca states that all specimens exposed by him to sunlight decomposed either on the first day or within a few days. But, at Woolwich, no single instance of such rapid decomposition of gun-cotton, made by the present process, has been noticed. A very gradual and slight development of gas occurs after a time, when the substance is exposed to sunlight; but the quantity which has been collected from specimens exposed at Woolwich to direct day and sun-light for two years and a half, is very small, and the gun-cotton has in all instances preserved its original appearance. Pélouze and Maury state that gun-cotton always decomposes perfectly within a few days, by exposure to temperatures of 55°—60° C. (131°—140° F.), and they lay great stress upon the explosion of a specimen directly it was introduced into a vessel heated to 47° C. (116·6° F.) But, at Woolwich, a specimen of ordinary product which has been exposed now for twelve months to 65° C. (149° F.), has evolved only a small quantity of gas, and retains its original appearance perfectly. Several specimens, after having been exposed for some hours to a temperature of 90° C. (194° F.), during which period some nitrous vapours were in all instances evolved, have since been exposed to light in closed vessels for about twenty months, and still retain their original appearance and explosive characters. Several large ammunition-cases, closely packed with gun-cotton, have been preserved for six months in a chamber, the temperature of which was maintained for three months at 49° C. (120° F.), and afterwards at 54°—55° C. (130° F.), arrangements having been made for periodically registering the temperature within the boxes, which were kept closed. In no

instance has the latter temperature risen to an extent to indicate serious chemical change, *i.e.*, it has always been below the temperature of the air in the chamber. These few examples of results already obtained are given to show that the behaviour of gun-cotton manufactured in England by Von Lenk's process does not, as yet, at all justify the condemnation which the material has recently received in France.

One most important part in connection with the preservation of gun-cotton appears to have been lost sight of by the French experimenters. The material may be most perfectly preserved, apparently for any period, either by immersion in water, or, still more simply, by being impregnated with just sufficient moisture to render it perfectly uninflammable. In this condition, gun-cotton is much safer than gun-powder can be rendered, even by mixture with very large proportions of incombustible materials. It may be transported with quite as much safety as the unconverted cotton; indeed, it appears to be very much less prone to gradual decay, if preserved for very long periods in a damp condition, than cotton or other vegetable substances. Many specimens of gun-cotton, preserved for several months in a very damp chamber, together with paper, cotton fabrics, and wood, retained their strength of fibre and all their original properties, and had no signs even of mildew upon them, while the paper fabrics in immediate contact with them had completely rotted away, and the wood was covered with fungi.

Considerable progress has been made in the manipulation of gun-cotton, with the object of modifying its explosive action. The rapidity with which gun-cotton burns *in open air* admits of ready and very considerable variation by applying the simple expedients of winding, twisting, or plaiting gun-cotton yarn of different sizes. But, although a mass of gun cotton may be made to burn in a comparatively gradual manner by being very tightly wound, a charge of the material in that form acts quite as destructively when exploded in the bore of a gun as an equal charge consisting of the yarn wound very loosely, because the pressure of gas established by the first ignition of the charge renders the compact packing of the gun-cotton powerless to resist the instantaneous penetration of flame between the separate layers of the material. The assertion that a power had been acquired of controlling the explosive action of gun-cotton in a fire-arm by simply varying the compactness with which the material was twisted or wound, has, therefore, proved quite erroneous. There are, however, two methods of reducing the rapidity of explosion of gun-cotton, which are much more likely to furnish successful results. The one consists in diluting the material by its admixture either with a less explosive variety of gun-cotton or with some inexplosive substance, such, for instance, as the cotton in its original form. The latter mode of dilution has recently been applied by Messrs. Prentice to the construction of cartridges for sporting purposes, and they describe the results already arrived at as very promising. The second method of controlling the explosion of gun-cotton consists in consolidating the material by pressure into compact homogeneous masses, and in confining the first ignition of such compressed gun-cotton in the bore of the gun, to certain surfaces. The gun-cotton fibre in the form of yarn or plait may be compressed into very compact masses by being rammed into strong cylinders of pasteboard

or other suitable material; but much more perfectly homogeneous and solid masses are produced, independently of cylinders or other cases, by a method which Mr. Abel has recently elaborated, and which consists in reducing the gun-cotton fibre to a fine state of division or pulp, as in the process of paper-making, and in converting this pulp by pressure into solid masses of any suitable form or density.

This method of operating affords also special facilities for combining both methods (dilution and compression) of reducing the explosive violence of gun-cotton. The material is, in fact, operated upon by this system, in a manner exactly corresponding to the processes by which the explosive action of gunpowder is regulated to so remarkable an extent. Some results, which are admitted by the most sceptical as encouraging, have already been arrived at, in the systematic course of experiments which are in progress, with the object of applying the methods of regulation, pointed out, to the reduction of gun-cotton to a safe form for artillery purposes. Its arrangement in a form suitable for small arms is a much less difficult problem, which may be considered as approaching a perfect solution. For employment in shells and for military mines, both land and submarine, the compressed or solid form of gun-cotton presents special advantages, on account of the great compactness which may be imparted to it; a given weight arranged so as to ignite instantaneously under pressure (*i.e.* in strong vessels), may be made to occupy the same space as an equal weight of gunpowder, whereas the forms of gun-cotton hitherto applied to these purposes occupy about three times the space of gunpowder.

Beautiful pyrotechnic effects may be readily produced by means of gun-cotton, though the absence of smoke, which, in some of its applications (especially in mines), would constitute an important advantage, detracts from some of the effects which may be obtained with pyrotechnic compositions. On the other hand, gun-cotton fireworks may be displayed in-doors without inconvenience.

There appears at present no reason to doubt that the application of gun-cotton, with great advantage to at least some of the more important purposes for which gunpowder is used, will, ere long, be fully established, and that this interesting explosive agent is destined to occupy a permanent and prominent position among the most important products of chemical industry.

F.A.A.

In a paper read before the Royal Society on the 19th of April, 1866, Professor Abel draws the following general conclusions :—

"1. The products obtained by submitting cotton-wool to treatment with the prescribed mixture of nitric and sulphuric acids, and to purification as directed by Von Lenk, are very uniform in character; they consist almost entirely of the most explosive known variety of gun-cotton or pyroxylin, which is insoluble in mixtures of ether and alcohol. This substance, when produced upon a manufacturing scale, contains from 1 to 2 per cent. of mineral substances; and a small proportion, varying with the quality of the cotton, of matters soluble in alcohol, partaking of acid properties, and consisting chiefly, if not entirely, of products of the action of nitric acid upon resinous or other bodies enclosed in the cotton fibre. There is also always present in the gun-cotton a small quantity (from 1 to 3

per cent.) of cellulose products of a less explosive character, soluble in mixtures of ether and alcohol, which result from the incomplete action of nitric acid upon small portions of the cotton operated upon.

"2. The gun-cotton, when purified as far as it is possible from foreign substances, soluble in alcohol and in ether and alcohol, furnishes analytical results which agree much more closely with those demanded by the formula

$$C_6 H_7 N_3 O_{11}, \text{ or } C_6 H_7 O_5, 3NO_2$$

than with the requirements of the formula

$$C_{24} H_{36} O_{18} 5N_2 O_5,$$

recently adopted for gun-cotton by Pélouze and Maury.

"3. If cotton-wool of great purity is digested for a period of about twenty-four hours with a considerable proportion of the prescribed acid-mixture (about 50 parts to 1 of cotton), it sustains an increase of weight ranging between 81·8 and 82·6 upon 100 of cotton. Lower results (between 78 and 80 per cent. increase) are obtained by digesting the cotton for a short period only, or for very considerable periods, by using a limited proportion of the acid (from 10 to 14 parts to 1 of cotton), by employment of acids of slightly lower specific gravities than those specified, and by operating upon cotton of somewhat lower quality. The digestion, for a second or third time, of products which have exhibited a comparatively low increase of weight, in an acid-mixture of the kind first used, or of greater strength, has the effect of raising the weight of the product to within the higher limits above named.

"The increase in weight which 100 parts of pure cellulose should sustain, theoretically, by complete conversion into a substance of the composition $C_6 H_7 N_3 O_{11}$, is 83·3, while, if converted into a substance of the formula

$$C_{24} H_{36} O_{18}, 5N_2 O_5,$$

the increase sustained by it only amounts to 77·8 upon 100 parts.

"4. Cotton-wool always contains, even after careful purification, small proportions of foreign organic substances, the presence of which, in the material submitted to treatment with the acids, must affect to some extent the quantity of the product obtained.

"5. It is extremely difficult, indeed apparently impossible, even in operating under most favourable conditions upon small quantities of cotton-wool, to convert this substance *completely* into the highest nitric product—the perfectly insoluble gun-cotton. Small quantities of gun-cotton soluble in ether and alcohol can always be extracted from the products; the quantities are only minute in the highest laboratory products, but they are always very appreciable in the most perfect manufacturing products. Their invariable formation must unquestionably cause the increase of weight sustained by cotton to be somewhat less than that which theory would demand.

"6. The long-continued digestion of the gun-cotton in the acid-mixture, the several mechanical operations to which it is submitted in the course of its purification, and above all, the solvent action exerted not only upon certain bye-products, but also upon the gun-cotton itself by the alkaline liquid in which it is boiled for a short time, are all sources of loss which, in examining into the results of a system of manufacture, must not be disregarded, and the existence

of which explains satisfactorily the difference observed between the weights of laboratory-products and those of manufacturing operations.

"7. In accepting the formula proposed by Pélouze and Maury for gun-cotton, it would be necessary to assume that the cotton-wool operated upon was pure cellulose; that the operation of conversion was an absolutely perfect chemical process; that there were no possible sources of loss in the production of the material; and that in all laboratory operations which had furnished an increase of weight above the theoretical demand (77·8 per cent.), some substance, differing in composition from the ordinary products of manufacture, must have been obtained.

"8. The identity in their characters, and close resemblance in composition, of the most perfect products of laboratory operations and of the *purified* products of manufacture, the very close approximation in the weight of the former to the theoretical demands of the formula

$$C_6 H_7 N_3 O_{11}$$

(which may be expressed as

$$C_6 H_7 O_5 3NO_4, \text{ or } C_{12} H_{14} O_7, 3N_2 O_5),$$

and the satisfactory manner in which the unavoidable production of somewhat lower results in the manufacturing operations admits of practical demonstration, appear to afford conclusive evidence of the correctness of either of those formulæ as representing the composition of the most explosive gun-cotton, and to demonstrate satisfactorily that the material, prepared strictly according to the directions perfected by Von Lenk, consists uniformly of that substance (now generally known as *trinitro-cellulose*) in a nearly pure condition."

PAPER VIII.

ACCOUNT OF THE

EXPERIMENTS ON DEMOLITION

WITH

GUN-COTTON CHARGES IN WOODEN BARRELS,

CARRIED OUT NEAR WIENER-NEUSTADT BY THE ENGINEER COMMITTEE, ON THE 13TH DEC. 1865,

*In presence of His Imperial Highness the Arch-Duke Leopold, Inspector-General of Austrian Engineers.**

COMMUNICATED BY MAJOR MILLER, R.A., V.C.

OBJECT.—The object of the experiments was to test the operation of wooden barrels charged with 25 lbs. of gun-cotton, such as are carried in the field-equipment-carts of the Imperial Engineers, against casemated works and unsupported ("frei-stehende") walls.

1ST TRIAL.—The first subject for experiment was a casemate 14 feet wide by 12 feet long; the arch having an angle of 120° with a loading ("nachmauerung") 1 foot thick at the top, and covered with 15 inches of earth. (See *a*, *b*, in Plate). The arch was firmly built of well-burnt bricks, and had been erected more than two years; the mortar appeared to be already well hardened. The loading was saddle-shaped, and consisted of brick-bats and rough stones.

A single barrel, charged with 25 lbs. of gun-cotton was embedded in the earth, over the crown of the arch, in contact with the loading. The ignition was effected by electricity, wire coated with gutta-percha being used to convey the current; by this means the circuit could be carried as a matter of precaution 500 paces to the rear of the explosion.

The effect produced is shewn on the plate, both in plan and in longitudinal section. (See *a′ b′*.) The arch and loading, forming together a mass of masonry, 3½ feet thick, were broken through, and an opening was made which measured 4 feet by 5 feet at the top, and 7 feet by 6 feet at the bottom. The other parts of the arch also received a violent shock, as was indicated by cracks, and by several bricks being displaced.

* From the official "Proceedings of the Austrian Engineer Committee" 1865; communicated by Baron Von Lenk to Lieutenant General Sabine, P.R.S., President of the Special Committee on Gun-Cotton. Translated by Major Miller, Royal Artillery, Secretary.

The parapet wall, 2 feet thick, over the rear of the casemate, was bulged out to the extent of 1 foot. (See section *a′ b′*.) A horizontal section of the bulge formed a triangle with a base of 9 feet, and a perpendicular of 1 foot on the outside face, but of only 4 inches on the inner face of the wall. Besides this the upper part of the wall was completely loosened.

On the face of the casemate itself it was remarkable that merely the two bricks immediately touching the key-bricks were pressed outwards, in such a manner that the side view of them presented a triangular appearance.

The opening produced in the arch and in the loading had its smallest diameter at the foot of the arch, and became larger both upwards and downwards. The broken materials lay immediately beneath the opening in a rough heap about 12 feet across and 3 feet high. In the surrounding walls there was no alteration visible. The crater in the earthwork above the loading was very regular, and had a maximum diameter of about 9 feet.

2ND TRIAL.—The second trial was against an unsupported brick wall, 3 feet thick and 6 feet high. (See *e, f,* in Plate.)

Against the back of this wall was placed a barrel, similar in all respects to the one used in the first experiment, and also fired by electricity.

The effect is illustrated on the plate, both in horizontal and cross section. (See *e′, f′*.) The wall was broken through, and separate bricks were thrown out at an angle of 14°; the breach had a breadth of 4 ft. 6 in., and a height of 5 ft. inside; outside it was 6 ft. wide, and 5 ft. 3 in. high. The greatest part of the débris lay immediately in and about the breach, so that the space clear enough for any one to see through was only 3 feet wide, and 2 feet high. The opening was smallest in the middle of the wall and widened out like a crater towards each side

The part of the wall above the breach was much shaken, and had sunk 6 in. in the middle. The wall also showed certain fissures radiating from the breach in several directions. In the corner where this wall joined a 4-ft. thick wall, which may be considered as a buttress, a separation 3 ft. 4 in. wide was caused between them. The greatest bulge of the 3 ft. wall was along the brink of the breach; here it amounted to 1 ft., and extended outwards, lessening by degrees, for a space of about 4 ft.

The effect in a downward direction was limited at the outer face of the wall to the level of the ground. Nevertheless, the wall generally was so much shaken that the part immediately above the breach could be pulled down by the mere use of the hands, and by clearing away the loose bricks, a practicable entrance for troops, 6 feet wide, could have been completed in a very short space of time.

3RD TRIAL.—This trial was against a wall 4 ft. thick at the lower part, up to a height of 9 ft., and 2 ft. thick to a further height of 6 ft.

At the foot of this wall a barrel similar to the others was embedded in the ground, with its head on a level with the surface, and was fired by electricity. (See *c, d.*)

The effect is shewn on the plan, both in horizontal outline and in cross-section. (See *c, d.*) The wall was broken through, and separate bricks thrown out at an angle of 7°. The breach measured inside 6 ft. wide by 5 ft. 3 in. high; and outside, 6 ft. 6 in. wide by 6 ft. high.

The greatest part of the débris lay, as in the case of the other wall, within and immediately in front of the breach. The opening left clear enough to be seen through was 2 ft. high and 2 ft. wide, very irregularly shaped. Immediately round the breach the brickwork was very much shaken, so that here also the opening could be enlarged by the mere use of the hands.

On the outer face of the wall there were two large cracks, which, starting from the right hand brink of the breach, at an angle of about 45°, traversed the whole of the wall that remained standing. Likewise on the inner face a great rent was produced, which began at the junction of the 3 ft. wall with the 4 ft. wall, and ran obliquely towards the breach. At the point where the neighbouring casemate formed what may also be regarded as a counterfort, a striking separation had taken place. The greatest bulge of the wall in a forward direction formed, as in the 3 ft. wall, a triangle with a base to the right and left of 4 ft. 6 in., and a perpendicular of 1 ft. The effect below took the form of a crater, ending at the outer face on the level of the ground, as with the 3-ft. wall.

The general effect was very violent and the shaking very severe.

CONCLUSIONS.—The effects of the three explosions above described, which are quite extraordinary when the smallness of the charges is taken into consideration, justify the following conclusions :—

(1.) Arched brickwork, up to a thickness of 2 ft. 6 in., with 1 ft. of loading above it, can be easily and certainly breached, if cases filled with 25 lbs. of gun-cotton are embedded above the crown of the arch, so as to rest on the loading, at a distance of 6 ft. from one another, and are simultaneously fired.

(2.) In brick walls, up to 3 ft. thickness, without supports, a practical breach can be made in the quickest manner if three or four such cases are placed against the wall at a distance of 6 ft. from one another, and simultaneously fired.

(3.) If such walls be 4 ft. thick, the cases placed at the aforesaid distance from one another must be buried about 20—24 in. deep at the foot of the wall, and be likewise simultaneously fired.

PAPER IX.

FOUNDATIONS ON TREACHEROUS SOIL*.

By CAPTAIN E. MITCHELL, R.E.

Of all the difficulties that have to be encountered in the construction of works of defence, perhaps the most trying arise from insecure or unstable foundations. They generally necessitate either the abandonment of a projected work, perhaps partially constructed, or a considerable outlay in the extremely unsatisfactory labour of patching, botching, or propping up a costly erection.

A fort or battery *can* be constructed almost anywhere, and the question is at once resolved into the most efficient and the least expensive method of doing so.

It may occur in practice that a position, upon which it is highly desirable to erect a fort or coast battery, is practically useless by reason of its geological formation. In place of solid rock or gravel, the underlying strata are little better than a thick bed of alluvial deposit, or a mixture of sand and mud.

Formations of this description are unable to support the weight of any structure unless it is spread over a very wide area, and even then the weight must not be great.

The American Indian, it is true, easily runs over the plains of frozen or soft snow with the aid of his snow shoes, as his weight is distributed over a large surface, but for all that he *does* sink a little at every step he takes.

A railway has been constructed across Chat Moss, partly upon the principle of spreading the weight to be supported over a large surface, but the burden of the passing trains that the boggy plain bears is a temporary not a permanent one; and it is probable that the iron road does yield in a small degree, just as thin ice will do under the evolutions of a rapid skater.

The object of this paper is to point out a method of constructing, by a peculiar system of piling, a perfectly stable and secure foundation upon a treacherous soil, whether it be silt, sand, mud, blue clay, or any other substance which generally presents engineering difficulties.

Although works of defence have been incidentally mentioned, it is not intended to mix up the question of screw piles with fortification or any precise building. The question is simply a design for foundations for massive walls and constructions in general upon treacherous sites. Upon good building ground the use of screw piles is not proposed, as other systems would be equally efficacious and less expensive.

* A Paper read at a Meeting at the War Office, on the 9th November, 1865.

The annexed drawings, which will be presently referred to, explain the proposal in detail; but, in the meantime, a general glance will be taken at screw piles. (See Plate 1.)

The screw pile is a bar of iron or wood, having at one end a broad screw of iron, the edges of the screw being either plain or serrated.

When driven into the ground the broad surface of the screw resists either downward pressure or upward strain in proportion to its area, and to the tenacity of the soil into which it has been driven.

Screw piles have been proved by experiment to be capable of penetrating any variety of soil or soft rock, whether it be sand, chalk, clay, gravel, soft sandstone, &c., &c.; they have also been driven through concrete after it had been for some time set.

Screw piles were invented a good many years ago by a namesake, but no connection of the writer of this paper. They were originally intended for, and have been extensively used for, moorings.

A screw, 4 ft. in diameter, has generally been found to answer all requirements; larger have been made and readily fixed; there is no difficulty in manufacturing or in fixing any sized screw.

A good deal was said about screw pile moorings in a paper read before the Institution of Civil Engineers, London, 22nd February, 1848; and there is no wish to reproduce here what has been brought forward by another. It may, therefore, suffice for the object of this paper to state that screw pile moorings have been laid down in the port of London, the harbour of Portsmouth, at Newcastle-upon-Tyne, at Glasgow, Greenock, and in nearly all the ports in the United Kingdom, as well as in several ports on the Continent and Australia, and have been the means of saving an immense amount of life and property. No instance is on record of screw pile moorings having been uprooted if sufficient chain be attached to the mooring, so as to allow for extraordinary tides or floods. It is evident by a glance at the sketch of a screw pile mooring, in Plate 4, that before it could be drawn up by main force a mass of ground above it, in the form of an inverted frustrum of a cone, must be displaced.

The breadth of the base of the cone would be in proportion to the tenacity of the ground, and the pressure of the volume of water above the moorings.

Several experiments were tried at Newcastle in the year 1844 to test the holding power of screw pile moorings, and the results were very satisfactory.

One trial was made with a small mooring weighing only 7 lbs., which was screwed into the ground upon the sandy shore on the south side of the Tyne, to a depth of 2 ft. 6 in., by two men in the course of a few minutes. It was then tested against an ordinary anchor of 2 cwt. by a strain applied by strong tackle pulled by horses. The anchor was dragged home, but the mooring was not moved.

Other trials were subsequently made with screws of larger diameter and more powerful anchors, but the screw moorings had the best hold.

Screw piles have been used with great success in the construction of lighthouses, beacons, piers, jetties, breakwaters, aqueducts, and viaducts.

Screw shoes have also been largely used in India for the posts which carry

the wires of the electric telegraph, and screw shoes have also been occasionally used in the British service to "take" the feet of tent poles.

In Plate 1, Fig 5 is shown a small screw suitable for use instead of tent pegs, but its weight, 5 or 6 lbs. has, it is believed, been a bar to its superseding the wooden peg. The writer cannot, however, help thinking that 4 screws might, in cases where transport could be easily and cheaply obtained, be used with great effect as auxiliaries, and as a substitute for a similar number of tent pegs. For sandy soil the ordinary wooden pegs in the service have but little hold in the ground; and even if the soil be of a tenacious character a gale will generally draw the wooden pegs, and sweep away the tents, but the screws would maintain their hold in the ground, and unless the ropes broke, it is believed that 4 screws would keep bell tents and small marquees, even in very stormy weather, from being blown away.

The foundation of the Maplin Sand lighthouse, laid at the mouth of the Thames in 1838, is composed of 9 wrought-iron piles, 5 inches diameter and 26 ft. in length, each terminated with a cast-iron screw 4 ft. in diameter. The piles were driven 22 ft. into the sand-bank, and the lighthouse is now there to answer for itself.

A lighthouse upon the Gunfleet Sands, on the east coast of England, commenced in 1852, and completed in 1855, also stands upon screw piles, screwed down 40 ft. into the sand.

As an example of a beacon, that at the Blackwater Bank, on the S.E. coast of Ireland, may be mentioned. A solitary screw pile stands there, with a huge ball at its summit, towering above the ocean.

The Courtown Pier in Wexford was erected in 1847 upon wrought-iron screw piles. But a work on a larger scale—the Madras Pier—is worthy of mention ; this pier is upwards of 1,000 feet long and 40 feet wide, and extends about 400 ft. beyond the water-line of the surf. The piles are screwed into the shore to a depth of from 11 to 19 feet. The pier was completed in the year 1859, and although in an extremely exposed situation, no portion has been washed away; for not only are the piles firmly driven into the ground, but they present an extremely small surface for the force of the waves to act upon.

The screw pile principle has also been adopted, with success, in the construction of some jetties at Jamaica.

The stone of which the Portland Breakwater, now in progress, is constructed, has been carried out into the sea by means of a timber stage placed upon screw piles 30 ft apart. The situation is a very exposed one, and the stage has been subjected to severe tests of wind and weather, but none of the piles have been injured.

As an instance of an aqueduct may be mentioned the one constructed for the purpose of carrying the pipe mains of the Chelsea Waterworks across the Thames between Fulham and Putney.

The apparatus for driving or screwing the piles into the ground simply consists of a stage and capstan, the latter being firmly keyed upon the wooden or iron bar to which the screw shoe is fitted, at a convenient height; the capstan bars are then shipped and the capstan forced round, it being occasionally raised as the

screw is driven into the ground, and again keyed upon the bar. This operation is continued until the piles are driven a sufficient depth into the ground.

The time required for driving screw piles is moderate enough; they are readily driven by hand, but where a number are to be put down, a steam-engine of 7 horse-power would be the most economical method.

In very soft ground the engine would put down a screw of 4 ft. diameter to a depth of 20 ft. in about eight minutes.

In blue or other clay, where a 3-ft. screw would be used, it would be driven to the same depth in about twenty minutes.

In driving through concrete or gravel, a 2-ft. screw would be employed, and would pass through it at the rate of 1 foot per hour.

In sand, a screw 2 feet 6 inches in diameter, would reach a depth of 10 feet in about twenty minutes.

In sandstone, a 1-ft. screw would be used, and could be readily driven at the rate of 1 foot per hour.

The drawings before us almost explain themselves. It is supposed that it may be desirable to construct a fort or battery of any given form or dimensions upon the sort of soil generally met with at the mouth of rivers; such a soil, for instance, as we should find about the mouth of the Thames—a mixture of silt, sand, mud, &c. It is assumed, for the sake of argument, that the fort is to be a semi-circular one, mounting 11 Armstrong guns, 7 in casemates, and 4 in embrasures on the terreplein, and capable of containing a garrison of sixty men. It is to be of the form and dimensions shewn in Pl. II. and III.

The site is 39·50 feet above high-water mark, and the muzzles of the guns in the casemates and embrasures 58·4 and 75·9 feet respectively above the water level.

The wall of the fort facing the sea is from 10 to 12 feet thick, faced with large blocks of granite, as shown in Pl. II. and III. These blocks of granite are backed with small rough pieces of similar material grouted in mortar. This is, perhaps, an unusual arrangement, but so many hundreds of tons of broken bits of granite are annually wasted in the quarries, that it has been possible to obtain them at a lower rate than Kentish rag stone or other suitable material.

The lower tier of casemates is of brickwork in mortar, the upper tier of brickwork in Portland cement, which is further strengthened by a layer of concrete 4 feet thick.

The gorge of the work is a defensible barrack of Kentish rag ashlar, two stories high, covered with Fox and Barrett's fire-proof roof.

In consequence of the treacherous nature of the soil the fort is supposed to be built upon screw piles, as shown in the plates.

The piles are to be of the best Dantzic timber, 12 inches by 12 inches, free from all defects, varying in length from 25 to 30 feet. The screw shoes are to be properly and securely adjusted to the ends. Plate I shows how this can be effected. When the piles are down to the required depth the tops will be cut off square and perfectly level with the ground. A mortice, 2 inches square and 2 inches deep, is then to be formed on the top of each pile to receive a slate plug 4 inches long and and 2 inches square; 8-in. *self-faced* York landings, 5 feet by 6

feet, are then to be placed upon the tops of the piles, the ground between being levelled to a uniform and tolerably even surface, so as to aid in supporting the York landings. The joints of the York landings are to be grooved (see Pl. III., Sections on AB, CD, EE), so as to receive a slate joggle, 4 inches wide and 1½ inches thick. A mortice should be cut on the under side of each York landing over the pile head, to receive the slate plug before described; two dovetailed dowels, 12 inches long, being let into each joint of the landings, flush with the top.

Upon this foundation, a fort or coast battery, or any other building, could, it is maintained, be safely built. The screw shoes used to support the heavy exterior wall and piers are to be 4 feet in diameter, except in a very few spots where the confined space causes 3-feet screws to be used. Those to support the barracks are to be 3 feet in diameter. From a series of experiments and the actual construction of various buildings, the following rule has been deduced, for estimating the weight in tons which screw shoes will *safely support*, viz. :—*Square the diameter in feet, and multiply by* 6.* Thus, the screws 4 feet in diameter, will each support a weight of 96 tons, and those three feet in diameter, 54 tons. Reckoning 12 cubic feet of granite to weigh 1 ton, 1 rod of brickwork 15 tons, Kentish rag 13 cubic feet to the ton, concrete 17 cubic feet to the ton, the York landings 1½ tons per square of 5 feet 6 inches, the weight of the superstructure, exclusive of the barracks but including its armament, is 7,311 tons. The weight of the barracks may be taken at 1,600. Annexed is a detailed statement, showing how these weights have been obtained. It will be seen by Plate II., that the fort is supported upon 212 piles, and the barracks upon 80. By the rule spoken of, the 212 screws, 4 feet in diameter, would support 20,352 tons, whereas they are required to support only 7,311 tons.

Again, the 80 screws, 3 ft. in diameter, would support 4,320 tons, but they are required to support only 1,600 tons.

There is therefore a great margin for safety, and, moreover, the large amount of weight borne by the York landings, which rest chiefly upon the natural soil, has not been taken into account.

The total cost of this foundation, including all necessary labour and pile-driving, will be £3,632, the piles and screw shoes, including fixing, being taken at £10 each, and the 178 squares of York landings at £4 per square of 5 ft. 6 in., including the fixing and setting.

In Pl. No. 4, the foundation is shown formed of timber. The piles are to be driven, and the tops cut square as before described. Waling pieces of Dantzic fir, 10 in. by 6 in., are to be run along the tops of the piles, to be properly scarfed at the joints, and secured with ¾-in. screw bolts (see section A B). The piles are to be braced together as shown, the braces to be Dantzic timber, 12 in. by 6 in., and their lower ends to rest upon oak cleats, 12 in. by 6 in., which will be firmly secured to the piles by iron spikes. The earth should be excavated to the bottom of the cleats over the whole surface, and clay or dry rubbish filled in and well rammed, and the top reduced to a perfectly level surface; 4-in. elm or other planking is then to be laid over the whole surface, the ends

* In very soft ground this formula, however, would not quite apply.

resting upon the waling pieces and secured to them. The cost of each square of this structure, including all labour and fixing, would be £7 12s. The price of the piles would be as before, £10 each, and the total cost £4,272 16*s.*, while by using York landings £640 16*s.*, would be saved.

This latter method (using wood) was the writer's first idea, but when he showed the design to Mr. H. Nixon, who is employed under him as temporary Clerk of Works, he suggested the use of York landings.

However, as it may yet be necessary to build a fort or coast battery on a treacherous soil in a country, such as Canada, where timber is abundant, and where York landings could not readily be procured, a third project for forming a secure foundation upon treacherous soil is submitted for consideration.

The piles are supposed to be driven and braced together as before described, and further secured by iron tie-rods. About 3 feet below the head of each pair of piles, and extending the distance between them, a rough baulk of Dantzic fir, 12 in. by 12 in., is to be firmly secured to the piles. The baulk also rests upon the earth between the piles.

Exactly between each pair of piles is to be fixed another baulk of similar description, but *above* the former one. Across each pair of piles a semi arch of eight rings of brickwork in cement is to be turned. The base of the arch rests upon the baulks first mentioned, and the haunches receive support from the other baulks alone.

It may be advisable in practice to have some 4-in. sheet piling along the outer piles in all the cases enumerated, to enclose the whole of the earth upon which the fort or battery is to be built, especially if it be of a very soft character, and thus prevent the possibility of the weight displacing the strata laterally.

In conclusion, the writer would urge for consideration that a few screw shoes should form an item of the Engineer equipment for service in the field. They would be found extremely useful in the construction of temporary bridges across streams or ditches too wide to be spanned without some support in the centre of the bridge. Also, in the formation of a rope bridge, seven or eight screw piles could be employed for securing the ends of the bridge. In soft ground four men would drive a 3-ft. screw to a depth of 10 ft. in six minutes. If the soil were clay they would perform the same task in about ten minutes.

E. M.

THAMES DEFENCES, ALLHALLOWS,
6th April, 1865.

ESTIMATE OF WEIGHT.

	TONS.
Brickwork	2,610
Granite	2,945
Concrete	1,242
Hoop Iron	20
York Stone	40
Kentish Rag	1,588
Slater	5
Carpenter and Joiner	40
Iron Work	25
Expense Magazines	50
Traverses	20
Stores, Ammunition, Shot, Shell, and Garrison	110
Fox & Barrett's Roof	12
York Landings	138
11 Guns on Carriages, and Platform	66
	8,911
Approximate weight of Barrack	1,600
Ditto ditto of Fort	7,311

DISCUSSION.

GENERAL SIR J. F. BURGOYNE, BART., G.C.B., in the Chair.

CAPTAIN BULLER.—Captain Mitchell has only taken into consideration cases where the pressure on the piles is uniform. How would he manage in a case in which there is unequal pressure, and where the greater weight of the fort is towards the front. That difficulty would arise more especially in the case of sea batteries, where, from the resistance of the soil being unequal, there is a lateral tendency towards the river side. How will he provide for that resistance?

CAPTAIN MITCHELL.—I do provide against that; because I do not use the squares as one square. Every one of the squares is braced together.

CAPTAIN BULLER.—Supposing there is not sufficient resistance in the soil in the front between the fort and the river, and there is a lateral tendency of the fort to go bodily down towards the river; how is that to be provided against?

CAPTAIN MITCHELL.—I try, as far as I can, to avoid that, by putting sheet piling round; and so enclosing the whole thing, like a coffer-dam, so, that if anything goes, the whole must go. I do not believe you could provide any power to make the whole go down; the power you would have to apply would be, practically, too enormous.

MAJOR RAVENHILL.—I have only one observation to make. I do not think that, under any circumstances, where the soil is treacherous, it is advisable to

use wood for the piles. I think that wherever the screw may be used, an iron pile is preferable to the wooden one.

Captain Mitchell.—I before stated that the screw pile is a bar of iron or wood, with a screw.

Major Ravenhill.—In the specification the piles were described to be of wood, 12 inches square. We had occasion to drive about 200 of them into the bed of the Southampton Water; but there our piles were of wood, and only 8 inches square, the screws being 2-ft. 6-in. in diameter. In many cases the wooden piles would not stand the pressure; they tore all to pieces, and we had great difficulty in getting them up. They, twisted and completely broke up. Iron should, I think, be used for the piles; and then they would in my opinion make a first-rate foundation.

Captain Rich.—I think the best form of screw pile has not been mentioned at all—which is, the cast-iron column. It is generally used in lengths of 10 or 12 feet. You begin by sinking the first length, which has a screw at one end and a flange at the other; and, as soon as it is down to the water's edge, or the edge of the mud, the additional lengths, which have flanges at each end, are bolted on in succession, until the screw has reached a firm stratum. In all cases where screws are used you will find that some will go much lower than others, owing to the soil; and, by having them in these lengths, you can obviate every difficulty of that kind. Again, I do not think they are adapted for the loose muddy soil for which they have been advocated. They seem very suitable for large loamy flats, where, after going to a certain depth, you get to gravel and other firm substances; but I have never yet known them used where they would have to be driven through firm substances. Sandstone itself is an excellent foundation, and you would not have to use piles at all. The same with gravel. When the screw pile is used you generally cease driving when you get to gravel, and you are very lucky if you do not break it before, because they are very apt to break. I cannot understand that the wooden ones are of any use, because they twist, and you have no means of increasing their length satisfactorily, as a splice would not be a satisfactory thing. There is one great difficulty in using these screws, viz., keeping them upright. They are very apt to go to one side, and then you have to take them out again. Screw piles are a cheap foundation rather than a good one. They are very useful where you want to get a cheap foundation, and the nature of the ground is soft, much cheaper than any other; but I think I have seen large platforms, consisting of beams and concrete, and beams alone, much more successfully used in muddy places. The latter is the foundation proposed for the Forth Bridge, which is to be 200 feet high, and about two miles long. It is brought forward by Mr. Bouche, C.E. He proposes to erect the piers on these floating platforms. This is a case where they have bored over 100 feet, and have not been able to get anything that would either hold a pile or a screw pile; therefore it remains to be either done by floating platforms, or by sinking cylinders, which latter form of foundation appears far the best for a permanent work; they are adopted for the Thames embankment, and are driven down by hydraulic pressure, or weight, and they seem a much better form of foundation for a battery than any

screws. Screws are more useful for conducting a roadway over a loamy, marshy flat. They are cheap, and that is their great value.

CAPTAIN MARSH.—The L. and N. W. Railway were constructing a bridge last year over the Mersey for a short line to Liverpool, and they rejected cast iron for wrought.

CAPTAIN BULLER.—There is this great advantage in cast iron over wrought, that it lasts a vast deal longer in sea water, where it is not subject to any violent blow. In all viaducts where the water is at all impregnated with salt, cast iron is preferred.

CAPTAIN WEBBER.—I want to ask if Captain Mitchell would inform us of the cases which he has known, or heard of, in which screw piles have been passed through sandstone and concrete. He has given us the time that it takes for the screw pile to pass through, and many here would feel interested in knowing the cases in which screw piles have been thus used.

CAPTAIN MITCHELL.—I have not been told the instances; I have merely been given them generally; but I have no doubt I could give them in the course of a day or two. I know an instance in which screw piles have been driven 12 feet into the coral reefs on the Gulf of Florida, as the foundation for a lighthouse.

The discussion then terminated.

In reply to the various objections which were raised at the discussion, Captain Mitchell has added the following rejoinder:—

In cases where there is not sufficient resistance in the soil between a fort built on screw piles and a river, and there is a lateral tendency of the work to go bodily down towards the river, as Captain Buller has suggested, this could be provided against not only by sheet piling, as I mentioned, but by giving the four exterior rows of piles a batter.

Major Ravenhill has given in some detail what happened to screw piles in the bed of the Southampton water. He says, "in many cases they tore all to pieces, and we had great difficulty in getting them up; they twisted and completely broke up."

I understand that in the cases where this occurred the screws came in contact with stumps of trees, old piles, &c., the existence of which had not been foreseen. For these positions either piles 12 in. square with 2 ft. 6 in. screws, should have been employed, or screws only 1 ft. 6 in. in diameter should have been used with the 8 in. by 8 in. timber. In the moderately hard ground *not one* single pile or screw twisted or broke, and all were readily and easily fixed.

With reference to Captain Rich's remarks, let me say that the cast-iron columns may be all very well for railway bridges, or for other works where it is not necessary to go a great depth into the ground; yet as it is necessary, on account of the enormous friction, to take out the core after each column has been screwed down from 6 to 10 feet, according to the nature of the soil; and although *it could be* done to an enormous depth, it is obvious that it would occupy a long time, and consequently be a costly process.

Solid wrought-iron piles entirely obviate this. They can be made in lengths and readily coupled together. As screws have, as I stated in my paper, been

proved to be capable of supporting a great weight in soft ground, I cannot agree with Captain Rich that they are not suitable for loose muddy soil. A magazine at Tilbury Fort has been built upon screw piles, which were driven from 5 to 8 feet into the clay on which the old magazine stood, the subsoil being peaty; and I believe the magazine is perfectly stable. Of course it is always advisable to go into the gravel, clay, or other firm substances; and this can readily be done, even to a depth of from 6 to 15 feet, without more than the ordinary wear and tear of the instruments.

Formerly I mentioned sandstone as a substance through which screw piles *could be* driven. It is, of course, an excellent foundation, so is gravel, if the layer be thick enough; but no engineer would, I think, like to place a massive building upon a bed of gravel 18 inches thick, where the stratum under it was peat —a very common formation. Moreover, if the gravel is at a great depth below the surface of the soil, how are you to put your masonry upon it, except at an enormous cost? About three years ago I saw solid wrought iron piles, 5 inches diameter, with cast-iron screws, put down at Her Majesty's India Store, Belvedere Road, to a depth of 4 feet, in a species of concrete or conglomerate, called by the workmen "the iron bound bed of the Thames," and none of the piles twisted or broke.

The floating platforms which Captain Rich has mentioned for a railway bridge are at present, I believe, only theoretical; it is a question whether they will support a railway so as to keep the line always true. They certainly cover a large surface, and so do screw piles, with the advantage of being fixtures.

Although Captain Rich asserts that "there is one great difficulty in using these screws—viz., keeping them upright," the fact is that such is not the case —there is no difficulty in keeping the screws upright. They have been used for bridges and piers, &c., where they were *obliged to be* put down true to 1-16 of an inch, in order that the holes in the girders might fit the piles.

In reply to Captain Buller's remark about cast-iron having an advantage over wrought-iron in sea water, I would remind him that the Maplin sand lighthouse has now stood nearly 28 years upon wrought-iron piles; and to borrow the words of an engineer, who recently inspected it, "Neither the piles, nor any portion of the structure, show signs of wear;" but the question of using wooden, cast or wrought-iron screw piles is only one of *detail*, and does not affect the general proposition to build massive works on screw piles.*

A pier has just been built at Colon Bay, Isthmus of Panama, for the Royal Mail Steam Packet Company, upon wrought iron screw piles, the screws being 4 feet 6 inches diameter. The ground to a depth of sixty feet is decidedly soft, being composed of mud or other very soft substance, and the screws are in the ground to a depth varying from 14 to 20 feet. The pier has been built in bays 20 feet square, and the piles are, therefore, 20 feet apart from centre to centre; yet each bay has, I am informed, supported, without showing any signs of sinking, the enormous testing weight of 36 tons.

E. M.

2nd April, 1866.

* The system could also be applied to retaining earth at a slope.

PAPER X.

A LIST OF BOOKS OF REFERENCE ON PROFESSIONAL AND SCIENTIFIC SUBJECTS,

BY LIEUT.-COLONEL A. C. COOKE, ROYAL ENGINEERS.

The object of this list is to furnish to Engineer Officers the names of reliable books of reference on the different professional and scientific subjects with which they have to deal.

The number of excellent works that are written on all subjects is very great, and causes some difficulty in making a selection, when it is desirable, as in this instance, to limit the list as much as possible. It cannot be expected that in all cases the works selected will be considered by every person the best, as this is to a certain extent a matter of opinion, but I believe that it will be found that every work given is a perfectly reliable one.

In almost every science two or three works are necessary for reference on the different portions of it, and in these cases it has generally been stated to what portion of the science the work refers. Civil Engineering treats of so many subjects, and these so interwoven, that it has been found necessary to enter more works for this than for other sciences, as some will be preferred for one portion and some for another.

The following arrangement has been followed throughout. The title by which the book is generally known is first given in large characters, then the title page in full, the publisher, size and price. Where thought necessary, a short abstract of the contents or explanatory note has been added.

I have endeavoured to get the opinion of those well qualified to form one in the different sciences, but I have, with very few exceptions, examined every work myself before entering it on the list; this has been possible from the facilities afforded by the libraries of the British Museum, Institution of Civil Engineers, Royal United Service Institution, and War Office. To the following I am specially indebted for assistance:—Captain Alexander Clarke, R.E., in charge of the astronomical observations and calculations of the Ordnance Survey; Colonel Hamley, R.A., Member of the Council of Military Education; Captain Hutchinson, R.E., Professor of Fortification at the Royal Military Academy, Woolwich; G. W. Hemans, Esq., Member of the Council of the Institution of Civil Engineers; Brig. General Lefroy, President of the Ordnance Select Committee; Lieut.-Colonel Lennox, R.E., V.C., Instructor in Field Fortifications, Chatham; Charles Manby, Esq., Hon. Sec. to the Institution of Civil

Engineers; Captain Parsons, R.E., in charge of the photographic operations of the Ordnance Survey; Captain Schaw, R.E., formerly Instructor in Telegraphy, &c., at Chatham; Professor Tennant; Professor Tyndall; Major Wray, R.E., Instructor in Architectural Drawing, Chatham, and Captain the Hon. G. Wrottesley, R.E., for a list of Engineering works which had been supplied to him as hon. sec. to the Royal Engineer Corps Libraries, by Mr. Bidder when President of the Institution of Civil Engineers.

I have added at the end a list of Weale's Rudimentary Series, as they are very cheap and portable, and will be found handy and reliable books of reference.

ACOUSTICS, SEE PHYSICS.

ARCHITECTURE.

1. RICKMAN'S GOTHIC ARCHITECTURE. An attempt to discriminate the styles of architecture in England from the Conquest to the Reformation, with a sketch of the Grecian and Roman orders, by the late Thomas Rickman, F.S.A., 6th edition, with considerable additions, chiefly historical, by John Henry Parker, F.S.A. Published by John Henry and James Parker, 1862. Size, 9 in. by 6 in. by $1\frac{3}{4}$ in. Price about 17s. 6d.

2. Weale's Series: 16, 17, 18, 19.

ARTILLERY.

1. DIDION, TRAITÉ DE BALISTIQUE—Par Is. Didion, Lieut. Col. d'Artillerie. Published at the Libraire Militaire de Leneveu, Paris. 2nd Edition, revised and enlarged. Size, $8\frac{1}{2}$ in. by $5\frac{1}{2}$ in. by 1 in.

This enters fully into all the investigations connected with the theory of projectiles.

The same author has also written COURS ÉLÉMENTAIRE DE BALISTIQUE, adopté par M. le Ministre de la Guerre pour l'enseignement des élèves de l'école spéciale militaire de Saint Cyr. Published at the Libraire militaire de Dumas, 1852. Size, 9 in. by $7\frac{1}{2}$ in. by $\frac{1}{4}$ in. This gives in a simpler and more elementary form, for the use of students, the matter contained in the former work.

2. PIOBERT, TRAITÉ D'ARTILLERIE THÉORIQUE ET PRATIQUE. 1st Part: Précis de la partie élémentaire et pratique, par G. Piobert. Troisième édition, revue et augmentée, 1852. 2nd Part: Partie théorique et expérimentale; 1st section: Propriétés et effets de la poudre, deuxième édition, revue et augmentée, 1859. Published by Bachelier, Paris. Size, $8\frac{1}{2}$ in. by $5\frac{1}{2}$ in. by 1 in. Price, 7 francs, (5s. 6d.) each vol.

The 1st part treats of the nature and effect of all sorts of arms, including swords, bucklers, muskets, rifles, cannon, &c., of bridge trains, the matériel and organisation of artillery.

3. ELEMENTARY LECTURES ON ARTILLERY, BY MAJOR OWEN. Prepared for the use of the Gentlemen Cadets of the Royal Military Academy. Printed at the Royal Artillery Institution, and sold by M. Boddy, bookseller, Woolwich. 4th edition, 1865. Size, $10\frac{3}{4}$ in. by $8\frac{3}{4}$ in. by 1 in. Price 15s.

This work treats in an elementary manner of guns, carriages, projectiles, equipment, and all matters connected with artillery.

4. NAVAL GUNNERY—SIR HOWARD DOUGLAS: A Treatise on Naval Gunnery, by General Sir Howard Douglas, Bart., G.C.B., G.C.M.G., D.C.L., F.R.S., dedicated by special permission to the Lords Commissioners of the Admiralty. 5th edition; revised with illustrations. Published by John Murray, 1860. Size, 9 in. by 6 in. by 2 in. Price, 21s.

This work is intended principally for Naval Gunnery, but it enters into the theoretical details and other matters applicable to land artillery. A continuation of it is being prepared by Lieutenant H. Hozier, 2nd Life Guards, Topographical Staff.

5. ARMY EQUIPMENT; PART 2: ARTILLERY. Equipment of Artillery, compiled by Major Miller, R.A., V.C., Topographical Staff, forming part 2 of the series relating to army equipment, prepared at the Topographical and Statistical Department, War Office, Colonel Sir H. James, Director. Printed by order of the Secretary of State for War at Her Majesty's Stationery Office, 1864. Size, 10 in. by 6 in. by 1 in. Price, 5s.

This work enters minutely into all the details of artillery equipment, including the guns in use, their calibre, range, &c. A fresh edition is in course of preparation by Lieutenant Barrington, R.A.

6. HANDBOOK FOR FIELD SERVICE, by Brig.-Gen. Lefroy, R.A., F.R.S., with the aid of several contributors. 3rd edition, revised. Published by John M. Boddy, Woolwich, 1862. Size, 5 in. by 4 in. by $\frac{3}{4}$ in. Price 7s. 6d.

This work gives, besides professional Artillery information, several tables and formulæ, notes on field sketching, military bridges, and other matters useful to an officer in the field. It is at present out of print, but a new edition is in course of preparation.

7. The notes issued from time to time by the Captain Instructors in the departments of manufacture at the Arsenal will be found valuable, such as

"Notes on the Manufactures of the Royal Carriage Department."

"Notes on the Matériel as at present issued by the Royal Laboratory."

"Notes on Gunpowder."

Lithographs of all the guns and a great deal of the matériel in use can be procured through the Royal Artillery Institution, Woolwich. See also DRILL.

ASTRONOMY.

1. LARDNER'S CABINET CYCLOPÆDIA, No. 43. ASTRONOMY BY SIR J. HERSCHEL, BART. Published by Longman. New edition, 1851. Size, $6\frac{3}{4}$ in. by $4\frac{1}{2}$ in. by 1 in. Price 3s. 6d. (reduced from 6s.)

This and the work next mentioned, which is an enlargement of it, are the best standard works on theoretical astronomy. They treat fully of all matters

connected with the constitution, motions and relations of all the heavenly bodies. They do not profess to give the details and tables necessary for making and reducing astronomical observations; for these Loomis' Astronomy should be consulted.

2. HERSCHEL'S OUTLINES OF ASTRONOMY. By Sir John F. W. Herschel, Bart., K.H., &c. Published by Longman. 7th edition, 1864. Size, 9 in. by 6 in. by 1¾ in. Price 18s.

This is an enlargement of the previous work. Their relations will be best shewn by the following extract from the preface. "The work here offered to the public is based upon and may be considered as an extension, and it is hoped an improvement, of a treatise on the same subject, forming part 43 of the Cabinet Cyclopædia, published in the year 1833."

3. LOOMIS' INTRODUCTION TO PRACTICAL ASTRONOMY; with a collection of astronomical tables by Elias Loomis, LL.D., Professor of Mathematics and Natural Philosophy in the University of the city of New York, author of a course of Mathematics, &c. Published by Harper and Brothers, New York, 1855. Size, 9½ in. by 6 in. by 1¼ in. Price 8s.

This work does not enter so much into the theory of the movements of the celestial bodies as Herschel's works previously-mentioned, but it gives complete information, with the necessary formulæ and tables, for making observations with every description of instrument and for working out all astronomical problems. It will be found sufficient for all ordinary purposes, but where the most refined instruments are employed, and the most accurate results possible sought for, one of the two works next mentioned should be used.

The following is a summary of its contents:—Principles to be observed in constructing an observatory—Description of celestial telescopes, the lenses used in them and methods of testing them—How to mount and adjust equatorial telescopes, transit instruments, mural circles, transit circles, altitude and azimuth instruments, sextants, repeating circles—Problems for the determination of the positions of heavenly bodies—The different measures of time used and methods of determining time by observations—Description of the different methods of determining latitude—Problems connected with the ecliptic—How to determine parallax—Calculations of eclipses and occultations—Methods of determining longtitude—List of observations. Tables required for working out astronomical problems—Catalogue of stars, whose elements have been determined.

4. BRUNNOW'S ASTRONOMY. Spherical astronomy, by F. Brünnow, PH. DR. Translated by the author from the 2nd German edition. Published by Assher and Co., London, 1865. Size, 9½ in. by 6 in. by 1 in. Price 16s.

For all ordinary observations, Loomis' Astronomy will be found sufficient, but where the greatest accuracy *possible* is desired, this work will be found useful. It does not contain tables.

The introduction contains short but comprehensive essays on (1). The transformation of co-ordinates and the formulæ of spherical astronomy. (2.) The theory of interpolation. (3.) Theory of several definite integrals used in spherical astronomy. (4.) Theory of the method of least squares. (5.) The development of periodical functions from given numerical values.

The first section contains problems on the transformation of co-ordinates from one system to another; on the diurnal motion; and on sidereal and mean solar time. The second section treats of the changes of the fundamental places to which the places of stars are referred; precession and nutation. The third section treats very fully of parallax, refraction, and aberration. The fourth section treats of the method of reducing the mean places of stars to the apparent places, and vice versâ; of the determination of the constants of refraction, aberration, nutation and precession, and the proper motion of stars. The fifth section is on the determination of azimuth, latitude and longitude, and on eclipses. The sixth section is on the figure of the earth. The seventh section is on the theory of astronomical instruments in general, and in particular of altazimuth, equatorial, prime vertical, and meridian transit instruments, &c.

5. SPHERICAL AND PRACTICAL ASTRONOMY. CHAUVENET. A manual of spherical and practical astronomy, embracing the general problems of spherical astronomy, the special application to nautical astronomy, and the theory and use of fixed and portable astronomical instruments, with an appendix on the method of least squares, by William Chauvenet, Professor of Mathematics and Astronomy in Washington University, St. Louis. 2 vols. Published by Trübner and Co., 1863. Size 10 in. by $6\frac{1}{2}$ in. by $1\frac{1}{2}$ in. Price 35s.

This book is similar in general character to Brünnow's, but more elaborate. It is got up in the most admirable manner and contains excellent tables.

6. Weale's Series, 96.

The Nautical Almanack, (see No. 10), will be required for making astronomical observations.

Physical Astronomy.

7. AIRY'S MATHEMATICAL TRACTS. Mathematical Tracts on the Lunar and Planetary theories, the figures of the earth, precession and nutation, the calculus of variations, and the undulatory theory of light. By George Biddell Airy, M.A., Astronomer Royal, &c. Published at Cambridge.
2nd edition, 1831. Size $8\frac{1}{2}$ in. by $5\frac{1}{2}$ in. by 1 in. Price 15s.

This valuable work contains treatises, remarkable for their clearness, upon the principal points of physical astronomy, viz., the motions of the moon and planets under the force of gravitation, and their perturbations; the mechanical theory of the figure of the earth, and of the movement in space of its axis of revolution. The calculus of variations is made as simple as the nature of the subjects admits of.

8. For those who wish to go still deeper into Physical Astronomy Laplace's Mécanique Analytique is recommended.

Nautical Astronomy and Navigation

9. RAPER'S NAVIGATION. The practice of Navigation and Nautical Astronomy, by H. Raper, Lieut. R.N., Secretary to the Royal Astronomical Society. Published by R. B. Bate, 7th edition, 1862. 2 vols. $8\frac{1}{2}$ in. by $5\frac{1}{2}$ by $\frac{3}{4}$ in. Price 16s. The first volume gives the problems necessary for navigation; the second, the tables for working them out.

10. THE NAUTICAL ALMANACK, and Astronomical Ephemeris. Published by order of the Lords Commissioners of the Admiralty. Sold by John Murray. Size 9 in. by 6 in. by $1\frac{1}{4}$ in. Price 2s. 6d.

This is published annually, and gives the positions of the heavenly bodies during the year and other data necessary for astronomical observations.

11. Weale's Series, 55, 56, 99, 100, 100*.

BLASTING AND QUARRYING, SEE CIVIL ENGINEERING.

BOTANY.

1. LINDLEY'S SCHOOL BOTANY, and Vegetable Physiology; or the Rudiments of Botanical Science, by John Lindley. A new edition with corrections, numerous additions, and more than 400 illustrations. Published by Bradbury and Evans, 1854. Size, 8½ in. by 5½ in. by ½ in. Price 5s. 6d.

This is a very good elementary work for beginners. It is recommended by the Society of Arts to candidates for their examinations.

2. MAGGILIVRAY'S MANUAL OF BOTANY: comprising Vegetable Anatomy and Physiology, or the structure and functions of plants, with remarks on physiology, by William Maggilivray, A.M., LL.D., &c. Published by Adam Scott, London. 2nd edition, 1853. Size, 7 in. by 4½ in. by ¾ in. Price 4s. 6d.

The object of this book is to describe the structure and physiology of plants, and not their classification.

3. LINDLEY'S VEGETABLE KINGDOM. The vegetable kingdom or the structure, classification, and use of plants, illustrated upon the natural system, by John Lindley, F.R.S., &c., with upwards of 500 illustrations. Published by Bradbury and Evans. 3rd edition, 1853. Size, 9 in. by 6 in. by 3 in. Price 30s.

This work gives a description of all the natural families of the plants of the world, with a catalogue of genera. The two works next mentioned enter into greater detail as regards English botany; both are standard works.

4. BABINGTON'S MANUAL OF BRITISH BOTANY—Containing the flowering plants and ferns, arranged according to the natural orders, by Charles Cardale Babington, M.A., F.L.S., &c. Published by John Van Voorst. 5th edition. With many additions and corrections, 1862. Size, 7¾ in. by 4½ in. by 1 in. Price 10s.

5. HOOKER AND ARNOTT'S BRITISH FLORA. Comprising the phenogamous or flowering plants, and the ferns, with numerous figures illustrative of the umbelliferous plants, the composite plants, the grasses, and the ferns; by Sir William Jackson Hooker, K.H., and George A. Walker Arnott, M.D. Published by Longman. 8th edition, revised and corrected, 1860. Size, 8 in. by 4½ in. by 1½ in. Price, 21s.

BRICK AND TILE MAKING, SEE CIVIL ENGINEERING.

BRIDGES, SEE DITTO.

CARPENTRY, SEE DITTO.

CHEMISTRY.

1. PRACTICAL CHEMISTRY. BOWMAN. An introduction to practical chemistry, including analysis, by John E. Bowman, F.C.S., late Professor of Practical Chemistry in King's College, London. Edited by Charles L. Bloxam, Professor of Practical Chemistry in King's College, &c. Published by John Churchill. 4th edition, 1861. Size 7 in. by $4\frac{1}{2}$ in. by 1 in. Price 6s.

This is a very clear and simple book, and gives directions for making qualitative analyses of the best known substances in nature, and several typical examples of quantitative analysis. There is no better book on analysis for a beginner, but for the general principles of Chemistry the work next mentioned should be consulted.

2. FOWNES' MANUAL OF CHEMISTRY. A Manual of Elementary Chemistry, theoretical and practical, by George Fownes, F.R.S., late Professor of Practical Chemistry in University College, London; 6th edition revised and corrected. Published by John Churchill, London, 1856. Size 7 in. by $4\frac{1}{2}$ in. by $1\frac{1}{2}$ in. Price 12s. 6d.

This book contains a very complete outline of the general principles of the science of chemistry, and an account of the history, composition, and uses of the more important organic and inorganic bodies with which we are acquainted.

3. HANDBOOK OF CHEMISTRY. ABEL AND BLOXAM. Handbook of Chemistry, theoretical, practical, and technical, by F. A. Abel, Director of the Chemical Establishment of the War Office, and C. L. Bloxam, Professor of Practical Chemistry in King's College, London, &c. Published by John Churchill; 2nd edition, 1858. Size 9 in. by 6 in. by 2 in. Price 15s.

This work gives, in a condensed form, a view of practical chemistry in its relations to the useful arts. Its aim is not so much to present a complete system of chemical philosophy as to be a text-book for the working chemist. It does not enter into organic chemistry, but embraces that which would be found of inorganic chemistry in Fownes' work, so far as is necessary for the manipulative chemist, and gives a more advanced course of qualitative and quantitative analysis than is to be found in that of Bowman.

4. MODERN CHEMISTRY. HOFMANN. Introduction to Modern Chemistry, experimental and theoretic, embodying twelve lectures delivered in the Royal College of Chemistry, London, by A. W. Hofmann, LL.D., F.R.S., V.P.C.S., Assayer of the Royal Mint, &c. Published by Walton and Maberly, 1865. Size 8 in. by 5 in. by $\frac{3}{4}$ in. Price 4s. 6d.

This work elucidates the leading principles of chemistry, according to new views of the constitutions and chemical properties of matter, which have been recently brought forward, but which have not as yet supplanted the hitherto recognized system of instruction.

5. Weale's Series 1.

For following up the different branches of chemistry more advanced works will be required, but it is not thought necessary to give them here.

CIVIL ENGINEERING.

General.

1. RANKINE'S CIVIL ENGINEERING. A manual of Civil Engineering, by William John Macquorn Rankine, Civil Engineer, LL.D., F.R.S., Regius Professor of Civil Engineering and Mechanics in the University of Glasgow, &c., &c., with numerous diagrams. Published by Charles Griffin and Co., London. 2nd edition, revised 1863. Size, 7½ in. by 5 in. by 2 in. Price 16s.

This work enters fully into the mathematical investigation of engineering problems, and deals largely with the calculus. Its contents are shewn in the following extract from the preface:—

"This work is divided into three parts. The first relates to those branches of the operations of engineering which depend upon geometrical principles alone, that is to say, surveying, levelling, and the setting out of works comprised under the general name of engineering geodesy or field work. The second part relates to the properties of the materials used in engineering works, such as earth, stone, timber, and iron, and the art of forming them into structures of different kinds, such as excavations, embankments, bridges, &c. The third part, under the head of combined structures, sets forth the principles according to which the structures described in the second part are combined into extensive works of engineering, such as roads, railways, river improvements, waterworks, canals, sea defences, harbours, &c.

2. CRESY'S ENCYCLOPÆDIA OF ENGINEERING. An encyclopædia of civil engineering, historical, theoretical, and practical, by Edward Cresy, Architect and Civil Engineer. Illustrated by upwards of 3,000 engravings on wood. Published by Longman. New edition with a supplement, in 2 vols., 1856. Size, first vol. 8½ in. by 6 in. by 1½ in.; second vol., 8½ in. by 6 in. by 2 in. Price £3 13s. 6d.

The greater part of the first volume is devoted to a history of the progress of civil engineering in all nations, beginning at the Phœnicians, including an outline of the nature and construction of the more important works executed by each, such as docks, harbours, lighthouses, bridges, roads, drainage works, railroads, &c. This volume contains also an article on geology and the different sorts of stones, bricks, and mortars used in building. The contents of the second volume are, outlines of geometry and properties of figures, principles of valuation of property, data for calculating the cost of different sorts of artificers' work, and the information and details necessary for the construction of all kinds of engineering works. This work is considered by some as rather obsolete.

3. COURS DE CONSTRUCTION. SGANZIN. Programme ou resumé des leçons d'un cours de construction avec des applications tirées spécialement de l'art de l'ingénieur des ponts et chaussées; ouvrage de feu M. J. Sganzin, quatrième édition, enrichie d'un atlas volumineux, entièrement réfondue et considérablement augmentée avec les notes et papiers de l'auteur, avec ceux de M. de Lamblardié fils, par M. Reibell, 1839. Published by Carilian Gœury et V. Dalmont, Paris, in 3 volumes, with a large atlas of plates. Size of each volume, 11 in. by 8½ in. by 1 in. Price about 7s. 6d. a volume.

The 1st volume treats of, resistance of materials, foundations in general, ordinary roads, railroads, bridges and viaducts in masonry, wood and metal, suspension bridges, moveable bridges.

The 2nd volume treats of, internal navigation on rivers, artificial navigation, irrigation, drainage, aqueducts, sewers, artesian wells, subjects connected with maritime navigation, viz, wind, waves, currents, sandbanks, ports, moles, breakwaters, jetties, basins, harbours, docks, &c.

The 3rd volume continues the subject of maritime navigation, and treats of removal of deposits, hydraulic works in connection with the construction, docking, loading, and repairing of ships of war and merchantmen, dry docks, maritime establishments, and arsenals &c.

4. MAHAN'S CIVIL ENGINEERING. An elementary course of Civil Engineering for the use of Cadets of the United States Military Academy, by D. H. Mahan, M A., Professor of Military and Civil Engineering in the Military Academy. Published by John Wiley, New York; 6th edition, with large addenda and many cuts, 1864. Size, 10 in. by 6 in. by 1¼ in. Price, 18s.

This work treats of mortars and cements, brick, properties of different sorts of timber, metals, varnishes, and paints; strength of different building materials exposed to different strains, masonry, iron and timber framing; construction of bridges, roads, railroads, canals, river and sea-coast improvements.

5. HEBERT. ENGINEERS' AND MECHANICS' ENCYCLOPÆDIA. Comprising practical illustrations of the machinery and processes employed in every description of manufacture of the British Empire; with nearly 2000 engravings by Luke Hebert, Civil Engineer, &c., &c. In 2 vols. Published by Thomas Kelly. A new edition, with considerable additions and improvements, 1856—61. Size 7 in. by 4 in. by 1½ in. Price £1 10s.

This work is arranged as a dictionary.

Smeaton's Reports, Tracts, and Eddystone Lighthouse are classical works in Civil Engineering, but they are scarce, bulky, and expensive, and not adapted for books of reference.

6. Weale's Series, 13, 14, 15, 15*, 22, 118, 119.

Blasting and Quarrying.

7. Weale's Series, 35.

Brick and Tile Making.

8. Weale's Series, 23, 24.

Bridges and Iron Structures.

9. HUMBER ON IRON BRIDGE CONSTRUCTION. A complete treatise on cast and wrought-iron bridge construction, including iron foundations; in three parts, theoretical, practical, and descriptive, illustrated by numerous examples drawn to a large scale, by William Humber. Vol. 1, text 15 in. by 10½ in. by 1 in. Vol. 2, plates 15 in. by 10 in. by 1½ in. Published by E. & F. N. SPON, 1861. Price £6 16s. 6d.

10. LATHAM ON WROUGHT-IRON BRIDGES. The construction of wrought-iron bridges, embracing the practical application of the principles of mechanics

to wrought-iron girder work, by John Herbert Latham, M.A., C.E., Fellow of Clare College Cambridge, with numerous detail plates. Published by Macmillan & Co., 1858. Size, 9 in. by $5\frac{3}{4}$ in. by $\frac{3}{4}$ in. Price 15s.

This work enters very fully into the theory and calculations of the weights and strains on all portions of girder work.

11. SHIELDS ON IRONWORK. The strains on structures of ironwork, with practical remarks on iron construction, by F. W. Shields, Member of Institution of Civil Engineers. Published by Weale, 1861. Size, $9\frac{1}{2}$ in. by 6 in. by $\frac{1}{4}$ in. Price 5s.

This is a very clear and practical work. It gives short practical rules, without the use of the calculus, for determining the strains on different portions of iron structures.

12. FAIRBAIRN'S RESEARCHES ON THE APPLICATION OF IRON TO BUILDINGS. On the application of cast and wrought-iron to building purposes, by William Fairbairn, C.E., F.R.S., F.G.S., &c. Published by Longman. 3rd edition, greatly enlarged with corrections and additions, to which is added a short treatise on wrought-iron bridges, with additions, &c., 1864. Size, 10 in. by $6\frac{1}{2}$ in. by $\frac{1}{2}$ in. Price 16s.

This work gives a series of experiments on cast-iron simple and trussed beams, and on wrought-iron beams and trellis girders, with the results deduced from them. Also the details of construction of fire-proof buildings. To the 3rd edition is added the adaptation of malleable iron beams, or girders, for the construction of bridges, with formula from which to calculate the strains on the struts and tension bars of lattice bridges.

13. HAUPT ON BRIDGE CONSTRUCTION. General theory of bridge construction, containing demonstrations of the principles of the art and their application to practice; furnishing the means of calculating the strains upon the chords, ties, braces, counter-braces, and other parts of a bridge or frame of any description, with practical illustrations, by Herman Haupt, A.M., Civil Engineer. Published by D. Appleton and Company, 200, Broadway, New York, 1856. Size, $9\frac{1}{4}$ in. by 6 in. by 1 in. Price 16s.

This is a very clear and practical work, and the calculations are for the most part made without the use of the calculus.

14. FAIRBAIRN ON CONWAY AND MENAI TUBULAR BRIDGES. An account of the construction of the Conway and Britannia Tubular Bridges, with a complete history of their progress from the conception of the original idea to the conclusion of the elaborate experiments which determined the exact form and mode of construction ultimately adopted. By William Fairbairn, C.E., &c. Published by Weale and Longman, 1849. Price £2 2s. Very scarce.

15. BAKER'S DIAGRAMS OF IRON GIRDERS. Giving weights of iron girders up to 200 feet span, by B. Baker. Published by Spon, 1866. Price 3s.

16. HAM AND HOSKING ON BRIDGE CONSTRUCTION*.

17. HODGKINSON ON CAST-IRON. Experimental researches on the strength and other properties of cast-iron, with the development of new principles, calculations deduced from them, and enquiries applicable to rigid and tenacious bodies generally, by Eaton Hodgkinson, F.R.S, with plates and diagrams. Published by Weale. 2nd edition, 1861. Size, $8\frac{1}{2}$ in. by $5\frac{1}{2}$ in. by $\frac{3}{4}$ in. Price 6s.

* This has been recommended to me but I have not had an opportunity of examining it.—A. C. C.

This gives the experiments made for determining the strength of iron under different circumstances, and the results deduced from them as to the best form and necessary dimensions of iron beams, pillars, &c., when subject to different strains. It forms a continuation of the 5th edition of Tredgolds' Practical Essay on the strength of cast-iron and other metals, containing practical rules, tables, &c., edited by Hodgkinson. The price of the two together is 16s.

18. Barlow on the Strength of Timber. A treatise on the strength of timber, cast and malleable iron, and other materials; with rules for application in architecture, the construction of suspension bridges, railways, &c.; and an appendix on the power of locomotive engines, and the effect of inclined planes and gradients, with 7 plates, by Peter Barlow, F.R.S., Member of the Institution of France, &c. A new edition revised and corrected by J. F. Heather, M.A., of the Royal Military Academy, Woolwich, to which is added an essay on the effects produced by causing weights to travel over elastic bars, by the Rev. Robert Willis, M.A., F.R.S., &c., with 9 illustrations. Published by Weale, 1851. Size, 8½ in. by 5½ in. by 1½ in. Price 16s.

19. Experiments on Wrought-Iron and Steel. Kirkaldy. Results of an experimental enquiry into the tensile strength and other properties of various kinds of wrought-iron and steel, by David Kirkaldy. Illustrated by numerous plates and diagrams. Printed for and sold by the author, at Glasgow. 2nd edition, 1863. Size, 9 in. by 6 in. by 1 in. Price 18s.

This work gives the details and results of a series of experiments on the tensile strength of all sorts of wrought-iron and steel, made by the author at the works of Messrs. Napier, in Glasgow, from 1858 to 1861. It treats of the tensile strength only, and does not comprise cast-iron, for which, see Hodgkinson.

20. Buck on Oblique Bridges. A practical and theoretical essay on oblique bridges, by George Watson Buck, C.E. 2nd edition, corrected, and with the addition of description to diagrams for facilitating the construction of oblique bridges, by W. H. Barlow, C.E. Published by Weale, 1857. Size, 11 in. by 7½ in. by [illegible] in. Price 12s.

This work gives the problems and practical instructions necessary for carrying out the details of oblique stone bridges.

21. Weale's series, 43, 124, 124*.

Carpentry.

22. Tredgold's Carpentry.—Elementary principles of carpentry; a treatise on the pressure and equilibrium of timber framing, the resistance of timber and the construction of floors, centres, bridges, roofs, uniting iron and stone with timber. With practical rules and examples to which is added an essay on the nature and properties of timber, including the methods of seasoning and the causes and prevention of decay, with description of the kinds of wood used in building; also numerous tables of the scantlings of timber for different purposes, the specific gravities of materials, &c., illustrated by 50 engravings and several woodcuts, by Thomas Tredgold, Civil Engineer, &c., &c. Third edition, corrected and considerably enlarged, with an appendix containing specimens of various ancient and modern roofs, by Peter Barlow, F.R.S., &c., &c. Published by John Weale; 4th edition, 1853. Size, [illegible] in. by 9 in. by 2 in. Price £2 2s.

23. Weale's Series, 123, 123*.

Contracts, Law of.

24. Weale's Series, 50.

Cranes, Constructing.

25. Weale's Series, 33.

Drainage and Sewage.

26. Weale's Series, 29, 30.

Embanking Lands from the Sea.

27. Weale's Series, 80*, 81*.

Foundations.

28. Weale's Series, 44.

Gas Works.

29. WEALE'S RUDIMENTARY TREATISE, 82**, 83*, 83 bis; GAS WORKS.—A treatise on gas works and the practice of manufacturing and distributing coal gas, with some account of the most approved methods of distilling coal in iron, brick, and clay retorts, and of the various modes adopted for purifying coal gas, including also a chapter on the hydro-carbon or water gas, and on the rating of gas works in parochial assessments, by Samuel Hughes, C.E. Published by John Weale. Size, 7 in. by 4 in. by $\frac{3}{4}$ in. Price 3s.

Hydraulics.

30. BEARDMORE'S MANUAL OF HYDROLOGY, containing: I, hydraulic and other tables; II, rivers, flow of water, spring wells, and percolation; III, tides, estuaries, and tidal rivers; IV, rainfall and evaporation; by Nathaniel Beardmore, C.E. Published by Waterlow & Sons, London; 1862. Size, 9 in. by 6 in. by $1\frac{1}{4}$ in. Price 7s. 6d.

This work enters into all matters connected with the fall, accumulation, flow, and discharge of water. The following are the principal subjects treated of: Rules and tables for calculating rate of discharge and velocities under all conditions, for sluices, tanks, reservoirs, sewers, rivers, drains, culverts, gas, and water pipes; expansion of water, steam, and gas; value of water power; water supply and flood discharges for different falls of rain; tables of useful weights and measures; properties of circles, logarithms, &c.; weight and strength of building materials; proportion between the fall, evaporation, and percolation of rain under different circumstances; discharge of rivers; velocity, rise, and fall of tides. It gives also the dimensions of iron pipes for different pressures of water, but not those of lead pipes.

31. STEVENSON ON HARBOURS.—The design and construction of harbours, by Thomas Stevenson, F.R.S.E., &c. Reprinted and enlarged from the article "Harbours," in the 8th edition of the Encyclopædia Britannica. Published by A. and C. Black, 1864. Size, 9 in. by $5\frac{3}{4}$ in. by $\frac{3}{4}$ in. Price 4s. 6d.

This work treats of the different classes of harbours; their geological features; generation and force of waves; construction of harbours in deep water and of tidal harbours; design of ground plan of harbours; materials employed and miscellaneous subjects connected with harbours.

32. Report of Royal Commission, 1859, on Harbours of Refuge. Blue book, with plates.

33. STEVENSON. IMPROVEMENT OF TIDAL RIVERS.—Remarks on the improvement of tidal rivers, illustrated by reference to works executed on the Tay, Ribble, Forth, Lune, and other rivers, by David Stephenson, F.R.S.E., &c. Published by Weale. Size, 9 in. by 6 in. by $\frac{1}{4}$ in. Price 4s. 6d.

34. BAIRD SMITH'S ITALIAN IRRIGATION.—Being a report on the agricultural canals of Piedmont and Lombardy, addressed to the Court of Directors of the East India Company, by R. Baird Smith, F.G.S., Captain of Engineers, Bengal Presidency. Published by authority. Vol. I, Historical and descriptive; Vol. II, Practical and legislative. Published by William Blackwood & Sons, 1855, Size, 9 in. by $5\frac{1}{2}$ in. by $1\frac{1}{4}$ in. Price £1 10s.

This work is the result of a mission on which Captain Smith was sent by the Directors of the East India Company to investigate the irrigation systems of Northern Italy, with a view to the improvement of those of India. The 1st volume gives a historical and descriptive account of the principal irrigation works of Piedmont and Lombardy, and of those of India in an appendix. The 2nd volume enters into the details of the works, including the necessary conditions for forming water meadows; the methods by which the water is conducted over them; the cost and profits of the different works; the methods adopted for measuring the quantity supplied so as to regulate the charges made to the different proprietors; and the legislative enactments on the subjects which have been made in Italy.

35. Weale's Series, 82***, 120, 121, 122.

There are other standard works, such as Rennie's British and Foreign Harbours; Minard's Works, &c., which are very bulky and expensive.

Lighthouses.

36. Weale's Series, 47, 48, 49; Lighthouses.

Limes, Mortars, and Cements.

37. PASLEY ON CEMENTS.—Observations on limes, cements, mortars, stuccoes, and concretes, and on Puzzolanas, natural and artificial, together with rules deduced from numerous experiments for making an artificial water cement equal in efficiency to the best natural cements of England, improperly termed Roman cements; and an abstract of the opinion of former authors on the same subject, by Major General Sir C. W. Pasley, K.C.B., F.R.S., &c., &c. Published by Weale; 2nd edition, 1847. Size, 9 in. by 6 in. by $\frac{3}{4}$ in.

38. PROFESSIONAL PAPERS OF THE CORPS OF ROYAL ENGINEERS, VOL. XI, NEW SERIES, 1862, Paper 3.—Observations on limes and cements, their properties and employment, by Captain Scott, Royal Engineers.

39. VICAT ON MORTARS AND CEMENTS.—A practical and scientific treatise on calcareous mortars and cements, artificial and natural; containing directions for

ascertaining the qualities of the different ingredients, for preparing them for use, and for combining them together in the most advantageous manner; with a theoretical investigation of their properties and modes of action. The whole founded upon an extensive series of original experiments, with examples of their practical application on the large scale, by L. J. Vicat, Engineer in chief of bridges and roads, formerly pupil of the "École Polytechnique," member of the Legion of Honour, &c, &c. Translated with the addition of explanatory notes embracing remarks upon the results of various new experiments, by Captain J. T. Smith, Madras Engineers, F.R.S., &c. Published by Weale, 1837. Size, 8½ in. by 5½ in. by 1 in. Price 3s. 6d. This work is very scarce.

40. TOTTEN ON MORTARS.—Essays on hydraulic and common mortars, and on lime burning; translated from the French of General Freussart, M. Petot, and M. Courtois, with brief observations on common mortars, hydraulic mortars, and concretes, and an account of some experiments made therewith at Fort Adams, Newport Harbour, from 1825 to 1838, by J. G. Totten, Lieut. Colonel of Engineers and Brevet Colonel, United States Army. Published by Wiley and Putnam, New York, 1842. Size, 9 in. by 6 in., by ¾ in. This work is out of print.

41. Weale's Series, 45.

Masonry and Stonecutting.

42. Weale's Series, 25, 26.

Mechanics.

43. MOSELEY'S ENGINEERING AND ARCHITECTURE. The mechanical principles of Engineering and Architecture, by Henry Moseley, M.A., F.R.S., Chaplain in ordinary to the Queen, Canon of Bristol, Vicar of Olveston, &c. Published by Longman. 2nd edition, 1855. Size, 9 in. by 5½ in. by 1¾ in. Price £1 4s.

This work treats of Statics and Dynamics; the pressure on and work done by different machines; the laws of stability of structures, including walls, piers, buttresses, arches, strains on loaded beams, &c. It embraces a most complete investigation of the principles of construction of machines and buildings.

44. WEISBACH. MECHANICS OF MACHINERY, &c. Principles of the mechanics of Machinery and Engineering, by Julius Weisbach, Professor of Mechanics and applied Mathematics in the Royal Mining Academy of Freiberg. In two vols., illustrated with one thousand engravings on wood. The translation from the German forms vols. 2 and 5 of the library of illustrated standard scientific works. The 1st volume contains the theory of mechanics; the 2nd, their practical application. Size, 8½ in. by 5½ in. by 1½ in. Price £2 2s.

45. FENWICK'S MECHANICS OF CONSTRUCTION. Including the theories of the strength of materials, roofs, arches, and suspension bridges, with numerous examples, by Stephen Fenwick. 8 vo., 1861. Price 12s.

46. APPLETON'S DICTIONARY OF MECHANICS. Dictionary of machines, mechanics, engine work, and engineering, illustrated with 400 engravings on wood, in 2 volumes. Published by D. Appleton and Co., New York. 2nd edition, 1857. Size, 10½ in. by 7 in. by 2¾ in. each vol. Price £2 10s.

The following extracts from the preface show the design of this work. "This dictionary is intended to be a dictionary of machines, mechanics, engine "work, and engineering; to present concisely and compendiously the details "of valuable machines in actual use, the laws of matter and their application, "the construction and proportions of parts of engines and millwork, together "with the most successful and useful examples in engineering." "To shew, "therefore, the advance of the mechanical arts, both here and abroad, to define "their exact position at the present time as far as possible, but more "particularly in regard to machinery, to make, as it were, a 'World industrial "exhibition' of useful machines, and a record of their application is the object "of the present work."

47. Weale's Series, 98, 98*, 114.

Doctor Robison's Mechanical Philosophy is a standard work, but it is of old date and very scarce.

See also MATHEMATICS.

Metallurgy.

48. PERCY'S METALLURGY. The art of extracting metals from their ores and adapting them to various purposes of manufacture, by John Percy, M.D., F.R.S., Lecturer on Metallurgy at the government school of mines. Published by John Murray, London. In 3 volumes, the two first only of which are published, 1st vol. 1861, 2nd vol. 1864. Size, 9 in. by 6 in., 1st vol. 1½ in. thick; 2nd vol. 2½ in. thick. Price £2 2s.

The first volume treats of fuel, including wood, peat, coal, charcoal, and coke; of fire-clays; of copper, zinc and brass. The second volume treats of iron and steel. The third volume will treat of the remaining metals.

49. Weale's Series.

Roads and Railroads.

50. A TREATISE ON ROADS BY SIR H. PARNELL. Wherein the principles on which roads should be made are explained and illustrated by the plans, specifications, and contracts made use of by Thomas Telford, Esq., on the Holyhead road, by the Right Honorable Sir Henry Parnell, Bart. Published by Longman, Rees, Orme, Brown, Green, and Longman, London, 1833. Size, 9 in. by 6 in. by 1¼ in. Price £1 1s.

51. GILLESPIE ON ROADS AND RAILROADS. A manual of the principles and practice of road making, comprising the location, construction and improvement of roads (common, macadamized, paved, plank, &c.), and railroads, by W. M. Gillespie, A.M., C.E., Professor of Civil Engineering in Union College. Published by A. S. Barnes & Co., New York. 6th edition, with additions, 1853. Size, 8½ in. by 5½ in. by 1 in. Price 9s.

This work enters into all the principles and details, the knowledge of which is necessary in the construction of roads, including laying-out, slopes, cross-section, materials, surface, cost, &c. A small portion is devoted to railroads.

52. DEMPSEY. PRACTICAL RAILWAY ENGINEER. A concise description of the engineering and mechanical operations and structures which are combined in the formation of Railways for public purposes, embracing an account of the principal works executed in the construction of railways to the present time,

with facts, figures, and data, intended to assist the Civil Engineer in designing and executing the important details required for those great public works. By G. Drysdale Dempsey, C.E. 4th edition, revised, and greatly enlarged. Published by John Weale, 1855. Size, 11 in. by 9 in. by 2¼ in. Price £2 12s. 6d.

53. PERDONNET. CHEMINS DE FER. Traité élémentaire de chemins de fer par Aug. Perdonnet, administrateur des chemins de l'est de la France et de l'ouest de la Suisse, membre du comité de direction des chemins de fer de l'est de la France, président honoraire de la société des Ingénieurs Civiles de France, &c., &c. Published by Langlois et Leclerq, Paris. 2nd edition, 1858, two volumes. Size, 9 in. by 5½ in. by 2 in. Price £1 10s.

This work gives a history of the progress of railways in different countries, and enters into all matters connected with their construction and cost, the different sorts of rails, chairs, &c., in use, carriages, locomotives, &c. The following extract from the preface shews the scope of the work. "Tracer en peu de mots l'histoire des chemins de fer, esquisser l'art de les construire, tel est le but que nous nous sommes proposé dans cet ouvrage."

54. Weale's Series, 46, 62, 62.*

Roofs.

55. Weale's Series, 124, 124.*
See also CARPENTRY and BRIDGES and IRON STRUCTURES.

Smoke, Prevention of.

56. Weale's Series, 125, 126.

Steam Engine.

57. TREDGOLD ON STEAM ENGINES.—1st Vol. The principles and practice and explanation of the machinery of locomotive engines in operation on the several lines of railway, exemplified in the examples constructed by different eminent engineers; with descriptive text, to which are added rules and regulations for the practical management of a locomotive engine, with experiments on the resistance of railway trains, by J. Sewell, Great Western Railway. The dimensions of the locomotive engine boiler in relation to its expansive powers, by R. Armstrong. The consumption of fuel and the evaporation of water, by E. Woods, Liverpool. Forming the 1st vol. of the new edition of Tredgold on the steam engine. 1850.

2nd Vol. The principles and practice and explanation of the machinery of steam navigation; examples of British and American steam vessels; and papers on the properties of steam and on the steam engine in its original application, originally compiled by Thomas Tredgold, C.E.; amended in this edition, with the addition of recent examples of the inventions of the Engineers of the east and west coasts of the Atlantic. 1851. Part 1, text; Part 2, plates.

3rd Vol. The principles and practice and explanation of the construction of the steam engine, including pumps, stationary and marine engines; examples of boilers used for steam navigation, and of those employed in Her Majesty's

Service; together with an example of the Turbine wheel; including also the new subjects contained in the present amended edition of the late Mr. Tredgold's book; a glossary of terms applicable to marine engines and boilers, with French and Spanish translations; and a general index, 1852-3. The whole consists of 3 vols. of text and one of plates. Size of each, 12½ in. by 10 in. by 1½ in. to 2 in. Published by Weale. Price £4 14s. 6d.

58. Bourne's Catechism of the Steam Engine. In its various applications to mines, mills, steam navigation, railways, and agriculture; with practical instructions for the manufacture and management of engines of every class, to which is prefixed an introductive description of all recent improvements, by John Bourne, C.E. Published by Longman. 11th edition, 1865. Size, 7 in. by 4½ in. by 2 in. Price 9s.

The same author has also published a handbook of the steam engine, containing all the rules required for the right construction and management of engines of every class, constituting a key to the catechism of the steam engine. 1865. Size, 7 in. by 4½ in. by 1½ in. Price 9s.

59. Weale's Series, 34, 78, 78*, 79, 79*, 80, 81.

Surveying.

60. Haskoll. The Practice of Engineering Field Work. Applied to land, hydrographic and hydraulic surveying and levelling for railways, canals, harbours, towns' water supply, ranging curves and centre lines, gauging streams, &c., including the description and use of surveying and levelling instruments, and the practical application of trigonometrical tables, illustrated by numerous plans and diagrams by W. Davis Haskoll, Civil Engineer, author of "Railway Contractors," &c. Published by Atcherley and Co., 1858. Size, 9 in. by 5½ in. by 1 in.

61. Weale's Series, 60, 61, 117.

See also Geodesy.

Water-Works, see *Hydrology*.

The Engineers' and Contractors' Pocket Book, published annually by Weale, contains a great deal of useful information on all engineering matters.

CLOCK AND WATCHMAKING.

1. Weale's Series, 67, 68.

CONTRACTS, see CIVIL ENGINEERING.

DICTIONARIES, see Weale's Series.

DRAINING, see CIVIL ENGINEERING.

DRAWING, GEOMETRICAL.

1. GEOMETRICAL DRAWING. BRADLEY. Elements of Geometrical Drawing, or Practical Geometry, plane and solid, including both orthographic and perspective projection, illustrated by 60 plates, engraved by J. W. Lowry, from original drawings; by Thomas Bradley, Professor of Geometrical Drawing at the Royal Military Academy, Woolwich, and King's College, London. Published by Chapman and Hall for the Committee of Council on Education, 1862, 2 parts. Size, 20 in. by 13 in. by ½ in. Price, two parts together, £1 5s.; 1st part, 16s.

"The first part contains all the elementary problems of plane and solid geometry, including the principles of perspective; the second contains an extension of the subjects, with the methods of representing curved surfaces by their generators, and the irregular surface of natural ground by contours; it also contains a selection of examples from various arts of construction to serve as copies for beginners." It is believed to be the only complete work on the subject in the English language. The drawings are very well executed.

2. Weale's Series, 76, 77.

DRILL AND BOOKS OF MILITARY REGULATIONS.

1. ARTILLERY MANUAL, 1860, demy 8vo., 304 pages. Price 2s. 4d. Pocket edition 1s.

2. ARTILLERY FIELD EXERCISES, with diagrams, 1861, demy 8vo., 246 pages. Price 5s. Pocket edition 1s.

3. CAVALRY, FORMATIONS AND MOVEMENTS, demy 12mo., 1862. Price 3s.

4. CAVALRY, BRIGADE AND DIVISIONAL MOVEMENTS, 1863, demy 12mo. Price 3s.

5. CAVALRY, SWORD, LANCE, AND CARBINE EXERCISES, 1865. Price 1s.

6. FIELD EXERCISE, 1862, POCKET EDITION, BY AUTHORITY.—Field exercise and evolutions of Infantry, as revised by Her Majesty's commands, 1861. Printed under the superintendence of Her Majesty's Stationery Office. Sold by W. Mitchell, Charing Cross, and other booksellers. Size, 5 in. by 3½ in. by 1 in. Price 1s. The price of the large edition is 4s.

Companion to the New Field Exercise, 1862, by Captain L. Flower, 3rd Royal Surrey Militia. This is a box of cardboard diagrams to facilitate learning drill. Sold by W. Mitchell. Size, 3 in. by 2 in. by 1 in. Price 2s. 6d.

7. MEDICAL REGULATIONS. Demy 8vo., 250 pages. Price 1s. 8d.

8. MILITARY TRAIN MANUAL. Demy 8vo., 72 pages. Price 1s.

9. PAYMASTERS' INSTRUCTIONS. Imperial 8vo., 96 pages. Price 1s.

10. PURVEYORS' REGULATIONS. Demy 8vo., 236 pages. Price 3s.

11. BUGLE SOUNDS, Infantry, by Edward Potter. Price 4s. 6d.

12. DRUM, METHOD OF BEATING, by Edward Potter. Price 4s. 6d.

13. FIFE, METHOD OF PLAYING, by Edward Potter. Price 3s.

14. GYMNASTIC EXERCISES. Military System of Maclaren's; crown 8vo., 194 pages. Price 1s. 6d.

15. MUSKETRY INSTRUCTION. Revised Regulations for the Army; crown 8vo. December, 1864. Price 1s.

16. Sword Exercise, Infantry. Price 1s.

17. Mutiny Act and Articles of War. Royal 12mo. Price 4s. Published annually.

18. Queen's Regulations and Orders for the Army, 1859; demy 8vo., 462 pages. Price 3s. 6d. Small edition, 1s.

19. War Office Regulations. Out of print. A new edition is being published under the title of Royal Warrant, Revised. Army Regulations, of which Vol. I, Part 1, Pay, was published February 3, 1866; the remainder is in course of preparation.

20. Army Equipment. A series of books prepared at the Topographical Department of the War Office, giving the articles of equipment, with their prices and weights, for every branch of the Service; printed by H.M. Stationery Office; sold by Mitchell and other booksellers. Part 1, Cavalry, 5s.; illustrations not yet issued. Part 2, Artillery, 5s.; illustrations not yet issued. Part 3, Engineers, 1st part with illustrations, 2s. 6d.; 2nd part in course of preparation. Part 4, Infantry, with illustrations, 4s. Part 5, Military Train, 2s. 6d.; illustrations not yet issued. Part 6, Commissariat, 1s. 6d.; illustrations not yet issued. Part 7, Hospital Service, with illustrations, 5s.

Size, 10 in. by 6 in. by 1 in. to ½ in.

21. Regulations for the Supply of Military Stores to an Army in the Field; by order of the Secretary of State for War, 26th February, 1866, $\frac{57}{\text{Gen No.}}$ $\frac{}{3316.}$ Published by H.M. Stationery Office.

This work gives the proportions of the different services forming a Corps d'Armée, and the numbers of all the articles required for its equipment.

22. D'Aguilar on Courts Martial, new edition, July, 1866. Price 7s.

23. Simmons on Courts Martial, new edition. Price 14s.

24. Manual of Military Law, by Colonel Pipon, new edition. Price 5s.

ELECTRICITY, see PHYSICS.

EMBANKING, see CIVIL ENGINEERING.

FORTIFICATION, see MILITARY ENGINEERING.

FOUNDATIONS, see CIVIL DITTO.

GAS, see DITTO DITTO.

GEODESY.

1. Frome's Outlines of a Trigonometrical Survey. Outline of the method of conducting a trigonometrical survey for the formation of geographical and topographical maps and plans; military reconnaissances, levelling, &c.;

with the most useful problems in geodesy and practical astronomy, and formulæ and tables for facilitating their calculation, by Colonel Frome, R.E., F.R.A.S., &c., &c. Published by John Weale, 59, High Holborn. Third edition, 1862. Size, $9\frac{1}{2}$ in. by 6 in. by 1 in. Price 12s.

This work gives the different processes for conducting a trigonometrical survey such as the measurement of the base line, triangulation, and filling in the triangles, &c.; directions for making a military reconnaissance and for sketching hill features; levelling, including the use and adjustment of the instruments, and method of contouring; how to obtain heights by the mountain barometer and temperature of boiling water; on colonial surveys; an outline of the method of conducting different geodesical operations connected with a trigonometrical survey such as the measurement of an arc of meridian, finding the difference of latitude and longitude of different stations, &c.; an outline of practical astronomy; problems for determining latitude, longitude, local time, the direction of a meridian line, the variation of the compass, with the tables necessary for their solution. This work is sufficient for ordinary local surveys; but for large surveys, where the triangulation is extensive and the method of least squares and other refined operations must be resorted to, one of the works next mentioned should be used.

2. Grandmessung in Ostpreussen, und ihre verbindung mit Preussichen und Russischen Dreieckskettren, mit 7 kupfertapeln; by Freiderich Wilhelm Bessel. Published in Prussia in 1838, 4to.

This is probably the best existing work on geodesy, but it is in German. For those who do not understand that language Francœur's work is recommended.

3. Francœur. Géodésie. Géodésie ou traité de la figure de la terre et de ses parties, comprenant la topographie, l'arpentage, le nivellement, la géomorphie terrestre et astronomique, la construction des cartes. 3rd edition, 1855. Size, 8 in. by 5 in. by 1 in. Price 10s.

Some of the methods given in this work are rather obsolete, but no better one is known for those to whom the language in which the "Grandmessung" is written is an objection.

4. Account of the Principal Triangulation of the Ordnance Survey. Account of the observations and calculations of the principal triangulation of the Ordnance Trigonometrical Survey of Great Britain and Ireland, and of the figure, dimensions, and mean specific gravity of the earth as derived therefrom. Published by order of the Master General and Board of Ordnance. Drawn up by Captain Alexander Ross Clarke, R.E., F.R.A.S., F.R.S., under the direction of Lieutenant Colonel H. James, R.E., F.R.S., &c., Superintendent of the Ordnance Survey, 1858. To be procured from the agents for the sale of Ordnance Survey publications. Size, 13 in. by 10 in., by $2\frac{1}{2}$ in. Size of volume of plates, 13 in. by 10 in. by $\frac{1}{2}$ in. Price £1 15s.

To those engaged in an extensive triangulation demanding the most refined observations and calculations, no work would be more useful than this, which gives the details of those actually made for the purposes of the Ordnance Survey of Great Britain and Ireland.

5. Weale's Series, 60, 61, 117.

See also Civil Engineering, 60.

GEOGRAPHY AND TRAVEL.

1. MURRAY'S ENCYCLOPÆDIA OF GEOGRAPHY. Comprising a complete description of the Earth, exhibiting its relations to the heavenly bodies, the physical structure and natural history of each country, and the industry, commerce, political institutions, and civil and social state of all nations; by Hugh Murray, F.R S.E., assisted by William Wallace, A.M., F.R.S.E., &c., Robert Jameson, F.R.S.E., &c., Sir W. J. Hooker, K.H., LL.D., and William Swainson Esq , F.R.S., &c.; illustrated by 82 maps drawn by Sidney Hall, and upwards of a thousand other engravings on wood. 2nd edition, thoroughly revised, and with a supplement bringing down the information to the present time. Published by Longman, 1844. Size, 9 in. by 6 in. by 3 in. Price £3.

Gazetteers.

These are necessarily bulky and expensive, the one given last is the least so.

2. FULLARTON'S GAZETTEER OF THE WORLD; or dictionary of geographical knowledge, compiled from the most recent authorities, and forming a complete body of modern geography, physical, political, statistical, historical, and ethnographical. Edited by a member of the Royal Geographical Society; illustrated with numerous woodcuts and 120 engravings on steel. Published by Fullarton, 7 Vols. Size, 10½ in. by 7 in. by 2 in. Price £10.

3. THE IMPERIAL GAZETTEER. A general dictionary of geography, physical, political, and descriptive, compiled from the latest and best authorities. Edited by W. G. Blackie, PH.D., Fellow of the Royal Geographical Society, with 700 illustrations, views, costumes, maps, plans, &c. Published by Blackie and Son, 1855, 2 Vols. Size, 11 in. by 7½ in. by 3 in. Price £4 15s.

4. GUIBERT. DICTIONNAIRE GÉOGRAPHIQUE et statistique, rédigé sur un plan entièrement nouveau, par Adrien Guibert. Ouvrage autorisé par l'université. Published by Jules Renouard et Cie.: Paris, 1850. Size, 9½ in. by 6½ in. by 3½ in. Price £1.

Map Making.

5. HUGHES'S MANUAL OF MATHEMATICAL GEOGRAPHY. Comprehending an inquiry into the construction of maps, with rules for the formation of map-projections; by William Hughes, F.R.G.S., late Professor of Geography in the College for Civil Engineers, author of a manual of geography, &c., &c. Published by Longman; 2nd edition, 1852. Size, 7 in. by 4½ in. by ½ in. Price 4s. 6d.

This is a very useful little book for all who have to construct maps. It gives a brief outline of the movements and general relations of the celestial bodies, and a detailed description of all the different methods of projection used for maps, whether for small or large portions of the Earth's surface, with rules for their construction.

Maps.

6. STIELER'S MAP OF GERMANY; with the Kingdoms of the Netherlands, Belgium, Switzerland, and the neighbouring countries as far as Paris, Lyons, Turin, Milan, Venice, Ofen, Kònigsberg, in 25 sheets; by Adolphe Stieler. Published by Justus Perthes Gotha; new edition, 1853. Scale, 1-800,000th. Size of each sheet, without margin, 12¾ in. by 12 in. It extends from the longitude of Paris to that of Konigsberg, in Prussia; and from the latitude of Schleswig to that of Milan. Price 17s.

This is one of the most useful maps, and certainly the cheapest, for general reference for passing military events, &c. It gives all the probable theatres of war in Europe, except the Danubian Principalities.

7. KLEIN'S MILITARY MAP OF GERMANY. In 25 sheets, by Anton Klein, Lieutenant in the Imperial Bavarian 11th Infantry Regiment. Published at Munich 1822—46. Scale, 1-500,000th. Size of each sheet, without margin, 20½ in. by 15½ in. It extends from the longitude of Orleans to that of Ofen, in Hungary; and from the latitude of Elbing, in east Prussia, to that of Milan. Price £4 12s.

This map is rather of old date, but it is very clear and good as a military map.

8. SCHEDA'S GENERAL MAP OF THE AUSTRIAN EMPIRE, with a large part of the neighbouring countries, by Joseph Scheda. Executed in the Imperial Military Geographical Institution. In 20 sheets, three of the eastern ones are not yet published. Scale, 1-576,000th. Size of each sheet, without margin, 19¾ in. by 17¾ in. It extends from the latitude of Dresden to that of Rome, and from the longitude of Bukarest to that of Basle. Price 5s. per sheet.

This is a beautifully-executed map, exceedingly minute in its details and names of places, so much so as to be in parts rather confused.

9. REYMANN'S MAP OF GERMANY. Published in Glogau, in 342 sheets; 81 of the Southern ones are not yet published. Scale, 1-200,000th. Size of each sheet, without margin, 13½ in. by 6¼ in. It comprises the whole of Europe from Paris on the west to the east frontier of Poland on the east, extending to the shores of the North and Baltic Seas. On the South it takes in as far as Trieste and the Lake of Geneva. Price 1s. per sheet.

This is on a larger scale than the preceding ones, and is an excellent map to use when reading military history.

Travel.

10. MANUAL OF SCIENTIFIC ENQUIRY. Prepared for the use of officers and travellers by various writers. Published by order of the Lords Commissioners of the Admiralty. 3rd edition, revised by the Rev. R. Main, with maps. Published by Murray. Post 8vo., price 9s.

11. GALTON'S ART OF TRAVEL, or hints on the shifts and contrivances available in wild countries. 3rd edition, revised and enlarged. Published by Murray, 1860. Post 8vo., price 7s. 6d.

GEOLOGY.

1. LYELL'S ELEMENTS OF GEOLOGY, or the ancient changes of the earth and its inhabitants, as illustrated by geological monuments, by Sir Charles Lyell, Bart., F.R.S., author of principles of Geology, &c. Published by John Murray, London. 6th edition, greatly enlarged, and illustrated with 770 woodcuts, 1865. Size, 9 in. by 6 in. by 2 in. Price 18s.

This is the best work that can be consulted for a history of the different stratified and plutonic rocks that form the earth's crust, their localities, extent, composition and fossil contents. It does not enter so largely into the general principles of the formation of rocks. This was more fully treated of by Sir C. Lyell, in his "Principles of Geology," which has been for some years out of print, but of which it is believed he is preparing a new edition.

2. JUKES' MANUAL OF GEOLOGY. The Student's Manual of Geology, by J. Beete Jukes, M.A., F.R.S., local director of the Geological Survey of Ireland, &c. Published by Adam and Charles Black, Edinburgh. A new edition, partially re-cast, and supplied with lists and figures of characteristic fossils, 1862. Size, 8 in. by 5½ in. by 2 in. Price 12s.

The contents of this book are divided under three heads. 1, Geognosy; 2, Palæontology; 3, the history of the formation of the series of stratified rocks. Under the first head are given the general principles which govern the form, composition, and arrangement of the different rocks forming the crust of the earth. Under the second, the laws which govern the distribution of the animal and vegetable kingdoms. Under the third, a chronological account of the different strata and their organic contents. This work supplies the place of Sir C. Lyell's "Principles of Geology," which is out of print.

3. Weale's Series, 3.

HEAT, SEE PHYSICS.

HYDRAULICS SEE CIVIL ENGINEERING.

LIGHT-HOUSES, SEE DITTO DITTO.

MAGNETISM, SEE PHYSICS.

MAPS, SEE GEOGRAPHY.

MASONRY, SEE CIVIL ENGINEERING.

MATHEMATICS.

Arithmetic.

1. COLENSO'S ARITHMETIC. Designed for the use of schools, to which is added a chapter on decimal coinage; by the Right Reverend J. W. Colenso, D.D., Lord Bishop of Natal. New edition, thoroughly revised, with the addition of notes and examination papers. Published by Longman, 1864. Size, 7 in. by 4½ in. by ¾ in. Price 4s. 6d. Recommended by the Society of Arts to candidates for their examinations.

2. Weale's Series, 84.

Book-keeping.

3. Weale's Series, No. 83. Recommended by the Society of Arts to candidates for their examinations.

Algebra.

4. TODHUNTER'S ALGEBRA. For the use of colleges and schools, with numerous examples; by I. Todhunter, M.A., Fellow of St. John's College, Cambridge. Second edition, revised. Published by Macmillan and Co., 1860. Size, 7 in. by 5 in. by 1 in. Price 7s. 6d. Recommended by the Society of Arts to candidates for their examinations.

5. Weale's Series, 86, 87.

Geometry and Mensuration.

6. POTTS' EUCLID. Euclid's Elements of Geometry, with explanatory notes and questions; by Robert Potts, 8vo., 1861. Price 8s. 6d.

The school edition of the above (first 6 books) 12mo., 1864. Price 4s. 6d. Recommended by the Society of Arts to candidates for their examinations.

7. LUND'S MENSURATION. Part 3 of his elements of geometry and mensuration; 8vo., 1854-9. Price 7s. Recommended by the Society of Arts to candidates for their examinations.

8. MOORE'S MENSURATION. Price 5s.

9. Weale's Series, 76, 77, 88, 89, 90, 93.

Trigonometry.

10. SNOWBALL'S TRIGONOMETRY. The elements of plane and spherical trigonometry, with the construction and use of tables of logarithms both of numbers and for angles; by J. C. Snowball, M.A., Fellow of St. John's College, Cambridge. Published by Macmillan, 8th edition, 1852. Size, 7½ in. by 5 in. by ½ in. Price 10s. 6d. Recommended by the Society of Arts to candidates for their examinations.

11. Weale's Series, 91, 92.

Mathematical Tables.

12. HUTTON'S MATHEMATICAL TABLES. Containing the common, hyperbolic, and logistic logarithms; also sines, tangents, secants, and versed sines, both natural and logarithmic, together with several other tables useful in mathematical calculations; also the complete description and use of the tables; by Charles Hutton, LL.D., F.R.S., &c. Published by Longman and others; 7th edition, with 7 additional tables of trigonometrical formulæ, by Olinthus Gregory, LL.D., 1830. Size, 9½ in. by 6 in. by 1¼ in. Price 12s.

13. Weale's Series, 94, 95.

Conic Sections, &c.

14. TODHUNTER'S TREATISE ON PLANE CO-ORDINATE GEOMETRY. As applied to the straight line and the conic section, with numerous examples; by I. Todhunter, M.A., Cambridge Published by Macmillan; second edition, revised, 1858. Size, $7\frac{1}{2}$ in. by 5 in. by $\frac{3}{4}$ in. Price 5s. Recommended by the Society of Arts to candidates for their examinations.

Calculus.

15. TODHUNTER'S DIFFERENTIAL CALCULUS. A treatise on the differential calculus, with numerous examples; by I. Todhunter, M.A., &c. Published by Macmillan, 3rd edition, revised, 1860. Size, $7\frac{1}{2}$ in. by 5 in. by 1 in. Price 10s. 6d.

16. TODHUNTER'S TREATISE ON THE INTEGRAL CALCULUS and its applications, with numerous examples; by I. Todhunter, M.A., &c. Published by Macmillan, 2nd edition, revised and enlarged, 1862. Size, $7\frac{1}{2}$ in. by 5 in. by $\frac{3}{4}$ in. Price 10s. 6d.

17. Ritchie's Differential and Integral Calculus, published by Taylor and Walton, 1847, gives a very clear explanation of the calculus and everything that an engineer wants to know for ordinary purposes.

18. Woolhouse's Differential and Cox's Integral Calculus, Parts 101 and 102, Weale's Series, are both excellent.

Principles of Mechanics.

19. PARKINSON'S ELEMENTARY MECHANICS. An elementary treatise of mechanics for the use of the junior classes at the University and the higher classes in schools, with a collection of examples, by S. Parkinson, B.D., Fellow and Prælector of St. John's College, Cambridge. Published by Macmillan, 3rd edition, revised, 1863. Size $7\frac{1}{2}$ in. by 5 in. by 1 in. Price 9s. 6d. Recommended by the Society of Arts to candidates for their examinations.

20. BESANT'S HYDROSTATICS. A treatise on hydrostatics and hydrodynamics, by W. H. Besant, M.A., Fellow and Assistant Tutor, St. John's College, Cambridge. Published by Deighton, Bell, and Co., 1859. Size, 9 in. by 6 in. by $\frac{3}{4}$ in. Price 9s. Recommended by the Society of Arts to candidates for their examinations.

21. TWISDEN'S PRACTICAL MECHANICS. Elementary introduction to practical mechanics, illustrated by numerous examples, being the 2nd edition of "Elementary Examples in Practical Mechanics," by the Rev. John Twisden, M.A., Professor of Mathematics in the Staff College. Published by Longman, 1863. Size, $7\frac{1}{2}$ in. by 5 in. by 1 in. Price 10s. 6d. Recommended by the Society of Arts to candidates for their examinations.

22. WALTON'S MECHANICAL PROBLEMS. A collection of problems in illustration of the principles of theoretical mechanics, by William Walton, B.A., Trinity College, Cambridge. Published by W. P. Grant, Cambridge, 1842. Size, 9 in. by 6 in. by 1 in. Price 16s.

23. ROUTH'S DYNAMICS OF RIGID BODIES. An elementary treatise on the dynamics of a system of rigid bodies, by Edward John Routh, M.A., Fellow and Assistant Tutor, St. Peter's College, Cambridge. Published by Macmillan, 1860. Size, $7\frac{3}{4}$ in. by $5\frac{1}{2}$ in. by 1 in. Price 10s. 6d.

24. Weale's Series, 97.

Practical Mechanics.

25. GOODEVE'S ELEMENTS OF MECHANISM. Designed for students of applied mechanics, by T. M. Goodeve, M.A., Professor of Mechanics at the Royal Military Academy, Woolwich, and late Professor of Natural Philosophy, King's College. Published by Longman, 2nd edition, enlarged and improved, 1865. Size, 7½ in. by 5 in. by ⅝ in. Price 6s. 6d. Recommended by the Society of Arts to candidates for their examinations.

26. RANKINE'S APPLIED MECHANICS. A manual of applied mechanics, by William John Macquorn Rankine, LL.D., &c. Published by Richard Griffin and Co., 1858. Size, 7¾ in. by 5 in. by 2½ in. Price 12s. 6d.

The object of this work, as stated in the preface, "is to set forth in a compact form those parts of the science of mechanics which are particularly applicable to structures and machines."

27. RANKINE. THE STEAM ENGINE. A manual of the steam engine and other prime movers, by William John Macquorn Rankine, C.E., LL.D., &c., with numerous diagrams. Published by R. Griffin and Co., 1859. Size, 7 in. by 5 in. by 1½ in. Price 12s. 6d.

See also PHYSICS and CIVIL ENGINEERING.

Mathematical Instruments.

28. Weale's Series, 32.

MEASURES, SEE WEIGHTS, &c.

MECHANICS, SEE CIVIL ENGINEERING AND MATHEMATICS.

METALLURGY, SEE CIVIL ENGINEERING.

METEOROLOGY.

1. HERSCHEL'S METEOROLOGY. From the Encyclopœdia Britannica, by Sir John F. W. Herschel, Bart., K.H. Published by Adam and Charles Black, 1861. Size, 6¾ in. by 4 in. by 1 in. Price 7s. 6d.

It is believed that this still remains the best standard work on the theories and facts connected with meteorology.

2. SIR H. JAMES. INSTRUCTIONS FOR TAKING METEOROLOGICAL OBSERVATIONS. With tables for their correction and notes on meteorological phenomena, drawn up by order of the Secretary of State for War; by Colonel Sir Henry James, Royal Engineers, F.R.S., M.R.I.A., F.G.S., &c. Published at the Topographical Depôt, 1860. Size, 9¾ in. by 6½ in. by ¾ in. Price 7s. 6d.

This work contains drawings and descriptions of meteorological instruments, instructions for taking observations with them, the tables necessary for their reduction, and some observations on meteorological phenomena.

See also PHYSICS.

MICROSCOPE.

1. THE MICROGRAPHIC DICTIONARY. A guide to the examination and investigation of the structure and nature of microscopic objects; by J. W. Griffith, M.D., F.L.S., and Arthur Henfrey, F.R.S., F.L.S., Professor of Botany in King's College, London. Published by John Van Voorst, Paternoster Row, London; 2nd edition, 1860. Size* 8 in. by 6 in. by 3 in. Price £2 2s.

This is a bulky and expensive work, but it is believed to be unrivalled as a book of reference for the investigator with the microscope. It gives detailed descriptions of all the parts of a microscope, and of all objects which can be made subjects of microscopic investigation, arranged alphabetically.

2. GRIFFITH'S TEXT BOOK OF THE MICROSCOPE. An elementary text-book of the microscope, including a description of the methods of preparing and mounting objects, &c., by J. W. Griffith, F.L.S., &c., &c.; with 12 coloured plates, containing 451 figures. Published by John Van Voorst, London, 1864. Size, 8 in. by 5 in. by $\frac{5}{8}$ in. Price 7s. 6d.

This book gives a description of the objects of microscopical investigation more commonly met with.

3. ON PREPARING AND MOUNTING MICROSCOPIC OBJECTS; by Thomas Davies. Published by Robert Hardwicke, London, 1864. Size, 7 in. by 4 in. by 1 in. Price 2s. 6d.

This book gives full directions for preparing and mounting every description of object by the most approved processes.

NOTE.—Microscopes can be obtained of all prices and sizes. The price of a first-class microscope, with two object glasses and two eye-glasses, varies from £20 to £30, according to the maker. Among the best makers are Ross, Powell and Leland, Ladd and Smith and Beck.

MILITARY ENGINEERING.

1. BOUSMARD. ESSAI GÉNÉRAL DE FORTIFICATION, et d'attaque et défense des places dans lequel les deux sciences sont expliquées et mises, l'une par l'autre, à la portée de tout le monde. Ouvrage utile aux militaires de toutes les places; par M. de Bousmard, Major au Corps des Ingénieurs de S.M. le Roi de Prusse. Published by Mangenil, Paris, 1837; 4 Vols. in 2. Size, $10\frac{1}{2}$ in. by $8\frac{1}{2}$ in. by $1\frac{1}{4}$ in. Price £2 2s.

This is given as one of the best of the old works on fortification.

2. BRIALMONT. DÉFENSE DES ÉTATS. Études sur la défense des états et sur la fortification; par A. Brialmont. Published by C. Mocquardt, Brussels, 1863; 3 Vols., with plates. Size, $9\frac{1}{2}$ in. by 6 in. by 1 in. Plates, 19 in. by 13 in. by $\frac{1}{2}$ in. Price about £3. It is difficult to be procured as it is already out of print.

This work treats of the strategical importance of fortresses and intrenched camps and of the different systems of fortifications, including the modern one as adopted in Germany, Belgium, England, &c.

3. LENDY'S TREATISE ON FORTIFICATION; or lectures delivered to Officers reading for the Staff; by Captain A. F. Lendy, F.G.S., F.L.S., &c. Published by Mitchell, 1862. Price £1 11s. 6d.

* The book is divided into 2 Vols., one of letter-press the other of plates, which are bound in one volume of the size given. It is believed that they can be also obtained bound in separate vols.

This treats of artillery, organization, guns, and projectiles; principles of field and permanent fortification; military posts, bridges; attack and defence of fortresses; the different systems of fortification; defence of frontiers.

4. MACAULAY'S FIELD FORTIFICATION. A treatise on field fortification and other subjects connected with the duties of the field engineer, illustrated with 12 plates; by J. S. Macaulay, Captain in the Corps of Royal Engineers. Published by Bosworth and Harrison, Regent Street, London. 5th edition, 1860. Size, 7 in. by 4 in. by $\frac{3}{4}$ in. Plates, 16 in. by 10 in. by $\frac{1}{4}$ in. Price 12s.

5. Elementary course of Field and permanent Fortification, and of the attack of Fortresses; by Captain Philips, R.E., of the Royal Military College, Sandhurst. To be obtained from Benjamin Pardon, Paternoster Row, London, 1866. Size, $10\frac{3}{4}$ in. by $8\frac{1}{2}$ in. by $\frac{5}{8}$ in.

6. Papers on the Arms in use and permanent Fortification, on the attack and defence of Fortresses, on Military Mining, and on the defence of Coasts. Compiled for the use of the Gentlemen Cadets at the Royal Military Academy, at Woolwich. Published by Weale, 1865. Size, $10\frac{1}{2}$ in. by $8\frac{1}{2}$ in. by $\frac{1}{2}$ in.

7. Notes on Military Bridges and Siege and Field Works. Compiled for the use of the Gentlemen Cadets, Royal Military Academy, Woolwich, by Captain Hutchinson, R.E., Professor of Fortification there. Size, $10\frac{1}{2}$ in. by $8\frac{1}{2}$ in.

8. JEBB ON OUT-POSTS. Practical treatise on strengthening and defending out-posts, villages, &c., in reference to the duties of Officers in command of picquets, 5th edition. Published at Egerton's Military Library, Whitehall. Size, $8\frac{1}{2}$ in. by $5\frac{1}{2}$ in. by $\frac{3}{4}$ in. Price 14s.

9. DOUGLAS ON MILITARY BRIDGES. An essay on the construction of military bridges and the passage of rivers in military operations; by General Sir Howard Douglas, Bart., G.C.B. Published by John Murray, 3rd edition, containing much additional matter, 1853. Size, $8\frac{1}{2}$ in. by $5\frac{1}{2}$ in. by $1\frac{1}{2}$ in Price 21s.

This is an admirable book, and probably the best on the subject.

10. Notes on Field Work Instruction, as carried on at the Royal Engineer Establishment, at Chatham, 1865. Printed at Chatham.

For firing mines by electricity, see TELEGRAPHY, 2.

See also Weale's Series, 35.

MILITARY HISTORY.

1. CUST'S ANNALS OF THE WARS. Annals of the wars of the 18th and 19th century. Compiled from the most authentic histories of the period, by the Hon. Sir Edward Cust, D.C.L., Lieutenant General in the British Army and Colonel of the 16th (Queen's) Lancers, 18th century. Vol. I, 1700 to 1739; Vol. II, 1739 to 1759; Vol. III, 1760 to 1783; Vol. IV, 1783 to 1795; Vol. V, 1796 to 1799. 19th century: Vol. I, 1800 to 1806; Vol. II, 1807 to 1809; Vol. III, 1810 to 1812; Vol. IV, 1813 to 1815. Sold by Mitchell and other booksellers. 1860. Size, 6 in. by 4 in. by 1 in. Price 5s. a volume.

This is a very useful book of reference; the notices of the campaigns are necessarily very brief.

Marlborough's Campaign.

2. COXE'S MEMOIRS OF THE DUKE OF MARLBOROUGH; with his original correspondence collected from the family records at Blenheim and other authentic sources, by William Coxe, M.A., F.R.S., F.S.A., Archdeacon of Wilts; a new edition, revised by John Wade, in 3 volumes, with atlas. Published by Henry Bohn, 1848. Size, 7½ in. by 5 in. by 1½ in. Atlas, 11 in. by 9 in. by ½ in. Price 10s. 6d.

This is a large voluminous work containing numerous particulars, but not always satisfactory to the military enquirer.

3. MARLBOROUGH'S DISPATCHES. The letters, and dispatches of John Churchill, first Duke of Marlborough, from 1702 to 1712; edited by General the Right Hon. Sir George Murray. Published by John Murray, 1845; 5 Vols. Size, 9 in. by 6 in. by 2 in. Price £5.

4. ALISON'S LIFE OF THE DUKE OF MARLBOROUGH. The military life of John, Duke of Marlborough, by Archibald Alison, F.R.S., author of the History of Europe, &c. Published by W. Blackwood & Sons, 1848. Size, 8½ in. by 5 in. by 1 in. Price 18s.

This is a readable summary of the two works previously mentioned.

Seven Years' War.

5. LLOYD'S WAR IN GERMANY. History of the late war in Germany between the King of Prussia and the Empress of Germany and her allies; by Major General Lloyd, who served several campaigns in the Austrian Army; 3 Vols. Size, 8½ in. by 10½ in. by 1 in. This work is out of print and difficult to be procured.

The 1st Vol. contains the campaign of 1756-7, with map of the seat of war, and plans of the battles of Lowositz, Prague, Chotzenitz or Kollin, Rosbach, Breslaw, Lissa, and Gross Iägersdorff.

The 2nd Vol. contains the campaigns of 1758-9, with a military map of the seat of war, and plans of the siege of Olmutz and of the battles of Zornsdorf, Hochkirchen, Paltzig, Cunnersdorf or Frankfort, and Maxen.

The 3rd Vol. contains an analysis of the Grecian, Roman, and modern military institutions; the philosophy of war; the policy of war; the principles of war demonstrated, and their application to the different powers of Europe.

Lloyd was an Englishman, a General in the Austrian Service.

6. Colonel Tempelhoff's History of the Seven Years' War, with remarks on General Lloyd's work. He was an Officer on Frederick's Staff.

7. CARLYLE'S HISTORY OF FREDERICK THE GREAT. History of Friederich II of Prussia, called Frederick the Great; by Thomas Carlyle, in 6 volumes. 1st Vol., 3rd edition; 6th Vol., 1865. Published by Chapman and Hall. Size, 9 in. by 6 in. by 1½ in. Price £4.

This work contains a great deal of information valuable to the student on every one of Frederick's campaigns, although not always complete as a military history. The description of the battles is very accurate and good, and more complete than the narrative of the strategical movements and plans of campaigns.

8. FRÉDÉRIC II. HISTOIRE DE MON TEMPS. This extends only to 1757.

9. JOMINI. HISTOIRE DES GUERRES DE FRÉDÉRIC II (sometimes called Traité des Grandes Opérations Militaires). Histoire critique et militaire des guerres de Frédéric II, comparées au système moderne, avec un recueil des principes les plus importans de l'art de la guerre; par le Lieutenant-Général Jomini, Aide-de-camp Général de Sa Majesté l'Empereur de Russie, &c. Troisième édition. Magimel, Anselin et Pochard: Paris, 1818; 3 Vols. Size, 8 in. by 5 in. by $\frac{3}{4}$ in. Price £2 2s.

This embraces all the campaigns of the seven years' war, with a brief account of the first Silesian war, and is minute in details, besides containing scientific comments.

Wars of the Revolution and Napoleon's Wars.

10. JOMINI. HISTOIRE DES GUERRES DE LA RÉVOLUTION. Histoire critique et militaire des guerres de la révolution, rédigée sur de nouveaux documens, et augmentée d'un grand nombre de cartes et plans; par le Lieutenant-Général Jomini, Aide-de-camp Général de Sa Majesté l'Empereur de Russie, Grand-croix de plusieurs ordres. Nouvelle édition, ornée des portraits des hommes remarquables de l'époque. Published at Brussels, 1840; 3 Vol., with plates. Size, $10\frac{1}{2}$ in. by 7 in. by 1 in. Plates, 20 in. by 13 in. by $\frac{1}{2}$ in. Price £4 4s.

This work embraces the period from 1788 to 1803. It is very minute and detailed, too much so indeed to enable the student to take a comprehensive view of any of the campaigns.

11. JOMINI. NAPOLÉON. Vie politique et militaire de Napoléon; par le Général Jomini. Bruxelles: Imprimerie Libraire Romantique, 1829. Size, 9 in. by 6 in. by $1\frac{1}{2}$ in. Price £4 4s.

This work gives very succinct accounts and brief scientific views of Napoleon's campaigns down to 1815.

12. THIERS. HISTOIRE DU CONSULAT ET DE L'EMPIRE. Faisant suite à l'Histoire de la Révolution Française; par M. A. Thiers. Published by Paulin, Paris; 20 Vols. Size, $8\frac{1}{2}$ in. by $5\frac{1}{2}$ in. by 1 in. Price £3 3s.

This embraces the period from 1800 to 1815; gives detailed information of the motives for adopting particular plans of campaign or making particular movements; describes operations very minutely, and contains references to documents and memoirs which have been recently brought to light and which were therefore not attainable by earlier writers; but there are numerous inaccuracies and inconsistencies caused by the author's Napoleonic and national prejudices.

13. DUMAS. PRÉCIS DES ÉVÉNEMENTS MILITAIRES; ou essais historiques sur les campagnes de 1799 à 1814, avec cartes et plans; par M. le Comte Matthieu Dumas, Lieutenant-Général des armées du Roi. Treuttel et Würtz, Paris, 1817; 19 Vols., with atlas. Size, 8 in. by 5 in. by 1 in. Atlas, 16 in. by $10\frac{1}{2}$ in. by $1\frac{1}{2}$ in. Price about £10.

14. CHARLES. PRINCIPES DE STRATÉGIE. Développés par la relation de la campagne de 1796, en Allemagne; ouvrage traduit de l'Allemand et attribué à Son Altesse Impériale l'Archiduc Charles, avec cartes et plans.

Tome premier renfermant les principes et leur application sur un théâtre de guerre supposé. Tome second renfermant la première période de la campagne de 1796. Tome troisième renfermant la deuxième période de la campagne de 1796.

À Paris, chez Magimel, Anselin, et Pochard, 1818; 1st and 2nd Vols. together. Size, 8 in. by 5 in. by 1¾ in.; 3rd Vol, 8 in. by 5 in. by 1 in. Price £1 1s.

Jourdan's narrative of the campaign is bound up with one edition of this work.

15. PELET. MÉMOIRES SUR LA GUERRE DE 1809 EN ALLEMAGNE. Avec les opérations particulières des corps d'Italie, de Pologne, de Saxe, de Naples, et de Walcheren; par le Général Pelet, d'après son journal fort détaillé de la campagne d'Allemagne; ses reconnaissances et ses divers travaux; la correspondance de Napoléon avec le major-général, les maréchaux, les commandans en chef, &c., accompagné de pièces justificatives et inédites. Roret, Libraire, Paris, 1824; 4 Vols. Size, 8 in. by 5 in. by ¾ in. Price £2 2s.

16. SÉGUR. HISTOIRE DE NAPOLÉON ET DE LA GRANDE ARMÉE, pendant l'année 1812; par M. le Général Comte de Ségur. Quatrième édition; Baudoin Frères, 1825, Paris; 2 Vols. Size, 8 in. by 5 in. by 1 in. Price 10s.

17. CATHCART. WAR IN RUSSIA AND GERMANY, 1812-13. Commentaries on the war in Russia and Germany, in 1812 and 1813; by Colonel the Hon. George Cathcart, with plans and diagrams. Published by John Murray, 1850. Size, 9 in. by 5½ in. by 1¼ in. Price 14s.

18. SIR R. WILSON'S PRIVATE JOURNAL. Private diary of travels, personal services, and public events, during mission and employment with the European armies in the campaigns of 1812-13-14, from the invasion of Russia to the capture of Paris; by Sir R. Wilson, C.M.T., &c., &c. Edited by his nephew and son-in-law, the Rev. Robert Randolph, M.A. Published by John Murray, 1861; 2 Vols. Size, 9 in. by 6 in. by 1½ in.

19. MUFFLING. PASSAGES FROM MY LIFE; together with memoirs of the campaigns of 1813 and 1814; by Baron von Müffling. Edited, with notes, by Colonel Philip Yorke, F.R.S. Published by Richard Bentley, 1853. Size, 9 in. by 5½ in. by 1¼ in. Price 14s.

He served on the Prussian staff and enters fully into the preliminary accounts.

20. KOCH. CAMPAGNE DE 1814. Mémoires pour servir à l'histoire de la campagne de 1814; accompagnées de plans, d'ordres de bataille, et de situations; par F. Koch, chef de bataillon d'état major. Chez Magimel, Anselin, et Pochard, Paris, 1819; 2 Vols., with atlas. Size, 8 in. by 5 in. by 1 in. Price £1 10s.

This is a very full and accurate account of the campaign.

Waterloo.

21. SIBORNE'S HISTORY OF WATERLOO. History of the war in France and Belgium in 1815, containing minute details of the battles of Quatre Bras, Ligny, Wavre, and Waterloo; by Captain W. Siborne, Secretary and Adjutant of the Royal Military Asylum, constructor of the Waterloo model; 3rd and revised edition, with remarks upon the Rev. C. R. Gleig's "Story of Waterloo." Published by T. and W. Boone, 1848. Size, 8 in. by 5½ in. by 1¼ in. Price £1 12s.

This is extremely trustworthy and most carefully compiled.

22. CHARRAS. HISTOIRE DE LA CAMPAGNE DE 1815 (Waterloo); par le Lieutenant-Colonel Charras. Bruxelles: Meline, Cans, et Compagnie; 2 Vols., Size, 7 in. by 5 in. by ¾ in. Price 7s. 6d.

This is very careful, complete, and scientific.

W

Peninsular War.

23. NAPIER'S PENINSULAR WAR. History of the war in the Peninsula and in the south of France, from the year 1807 to the year 1814; by Major General Sir W. F. P. Napier, K.C.B., &c. New edition, revised by the author. Published by Thomas and William Boone, 1856; 6 Vols. Size, 7½ in. by 4 in. by 1¾ in. Price £3.

24. BRIALMONT AND GLEIG. LIFE OF THE DUKE OF WELLINGTON. History of the life of Arthur, Duke of Wellington, from the French of M Brialmont, Captain of the Staff of the Belgian army; with emendations and corrections by the Rev. G. R. Gleig, M.A., Chaplain General of the Forces, and Prebendary of St. Paul's. Published by Longman, 1858; 3 Vols. Size, 9 in. by 5 in. by 1½ in. This has been published since compendiously in one volume. Price 5s.

25. HAMLEY'S WELLINGTON'S CAREER. Gives short general views of the campaigns. Published by Blackwood. Size, 7 in. by 4½ in. Price 2s. 6d.

Italian War, 1848-9.

26. GUERRE DE L'INDÉPENDANCE ITALIENNE EN 1848 ET EN 1849; par le Général Ulloa. Tome premier: événements antérieurs à la guerre; campagne de Piedmont, et guerre dans la Vénétie. Tome second: affaires de Toscane et de Sicile; guerre de Rome; blocus et siége de Venise. Paris: Librairie de L. Hachette et Cie., 1859; 2 Vols. Size, 8¾ in. by 5½ in. by 1 in. Price 15s.

Italian War, 1859.

27. MILLER'S ITALIAN CAMPAIGN, 1859. A study of the Italian campaign in 1859; by Major Miller, R.A., V.C. Extracted from the proceedings of the Royal Artillery Institution; Michell, 1860. Size, 9½ in. by 6 in. by ¼ in. Atlas, 17 in. by 11 in. by ⅛ in. Price 10s. 6d.

This is a clear, compact, and very accurate work.

28. RELATION DE LA CAMPAGNE D'ITALIE EN 1859. Relation historique et critique de la campagne d'Italie en 1859; par Ferdinand Lecomte, Capitaine à l'état-major fédéral Suisse. Paris: Tanera, 1860; 2 Vols. Size, 9 in. by 6 in. by 1 in. Price 15s.

This is a clear and very accurate work.

American War of Independence.

29. MARSHALL'S LIFE OF WASHINGTON. The life of George Washington, written for the use of schools; by John Marshall, late Chief Justice of the Supreme Court of the United States. Published by James Crissy, Philadelphia, 1838. Size, 7½ in. by 4½ in. by ¾ in.

This is scarce and difficult to be procured. It is quoted at £2 2s. An account of the war will be found in Cust's Annals of the Wars.

American War, 1812-14, and Indian Wars.

30. ALISON'S HISTORY OF EUROPE. From the commencement of the French Revolution in 1789, to the restoration of the Bourbons in 1815; by Archibald Alison, F.R.S.E., Advocate; 2nd edition. Published by William Blackwood; 10 Vols. Size, $8\frac{1}{2}$ in. by $5\frac{1}{2}$ in. by $1\frac{1}{2}$ in.

Continuation from the fall of Napoleon, in 1815, to the accession of Louis Napoleon in 1852; 8 Vols., with index.

American War, 1861-65.

31. HISTORY OF THE AMERICAN WAR; by Lieut. Colonel Fletcher, Scot's Fusilier Guards. Vol. 1: first year of the war, 1861-2; Vol. 2: 1862-3. Published by Richard Bentley, 1865. Size, 9 in. by 6 in. by $1\frac{1}{2}$ in. Price £1 16s.

32. CAMPAIGNS IN VIRGINIA, MARYLAND, &c.; by Capt. C. C. Chesney, R.E., Professor of Military History, Staff College. Volume 1st: to the close of the campaign of Chancellorsville; Vol. 2nd: continuing the history to the end of the third year of the war; with maps. 2nd edition, revised and enlarged. Published by Smith, Elder, & Co., 1864. Size, 8 in. by 5 in. by 1 in. Price 15s.

Strategy and Tactics.

33. HAMLEY'S OPERATIONS OF WAR; explained and illustrated by Edward Bruce Hamley, Colonel in the Army, Lieutenant Colonel Royal Artillery, &c. Published by William Blackwood, 1866. Size, $9\frac{1}{2}$ in. by 7 in. by $1\frac{3}{4}$ in. Price £1 8s.

In this work the principles of war are deduced from the operations of different campaigns.

34. JOMINI. PRÉCIS DE L'ART DE LA GUERRE; ou nouveau tableau analytique des principales combinaisons de la stratégie, de la grande tactique, et de la politique militaire; par le Baron de Jomini. Nouvelle édition, considérablement augmentée. Paris: chez Anselin, 1837. Size, $8\frac{1}{2}$ in. by $5\frac{1}{2}$ in. by $1\frac{1}{2}$ in. Price 9s.

35. COURS DE TACTIQUE; par G. H. Dufour, ancien instructeur du Génie et de l'état-major à l'école militaire de Thun, quartier-maître général de la confédération, officier de la légion d'honneur, &c. Librairie Cherbuliez et Cie., 1840. Size, 8 in. by $5\frac{1}{2}$ in. by $1\frac{1}{4}$ in. Price 9s.

This work treats of strategy as well as of tactics.

36. LALLEMAND. TRAITÉ DES OPÉRATIONS SECONDAIRES DE LA GUERRE. Traité théorique et pratique des opérations secondaires de la guerre, accompagné d'un atlas en 4to., contenant quarante-quatre plans topographiques, avec sommaire et légende pour servir à l'intelligence des mouvements; instruction sur la figure du terrain; tables, tableaux, &c.; par A. Lallemand, chef de bataillon au corps royal d'état-major, chevalier de l'ordre royal et militaire de Saint-Louis, de la légion d'honneur, &c. 2 Vols., with plates. Freuttel et Würtz, Paris, 1824. Size, 8 in. by 5 in. by $\frac{3}{4}$ in. Atlas, 12 in. by 9 in. by 1 in. Price £2.

MINES, SEE MILITARY ENGINEERING.

MINERALOGY.

1. DANA'S MANUAL OF MINERALOGY. Including observations on mines, rocks, reductions of ores, and the applications of the science to art, with 260 illustrations, designed for the use of schools and colleges; by James Dana, A.M., &c., &c. Published by Trübner and Co.; new edition, revised and enlarged, 1864. Size, 8 in. by 5 in. by 1¼ in. Price 7s. 6d.

This work commences with a description of the different characteristics of minerals, such as their crystalline forms, physical and chemical properties, &c. It gives a list of all mineral bodies, arranged in natural order, showing their characteristics; and another arranged according to their chemical and physical properties, to facilitate the determination of an unknown mineral. It gives also directions for the use of the blow-pipe; a description of the different forms of rocks; and a list of implements and materials necessary for making mineralogical investigations.

2. SCHEERER AND BLANFORD ON THE BLOW-PIPE. An introduction to the use of the mouth blow-pipe; by Doctor Theodore Scheerer; to which is added a description of the blow-pipe characteristics of the more important minerals; by Henry F. Blanford. Published by Williams and Norgate; 2nd edition, 1864. Size, 6¾ in. by 4 in. by ½ in. Price 2s. 6d.

This is a very useful little book for those who wish to test minerals. It gives practical directions for the management of the blow-pipe and for the use of re-agents and tests; and a list of all the ordinary mineral bodies, showing their behaviour under the blow-pipe.

3. Weale's Series, 4, 5.

Boxes of mineralogical and geological specimens for the use of students, varying in price from 2 to 500 guineas, are sold by Tennant, 149, Strand.

MONEY, SEE WEIGHTS, &c.

MORTARS, &c., SEE CIVIL ENGINEERING.

NAVIGATION, SEE ASTRONOMY.

OPTICS, SEE PHYSICS.

PAINTING.

1. Weale's Series, 27, 28.

PERSPECTIVE.

1. Weale's Series, 20, 21.

See also DRAWING GEOMETRICAL.

PHOTOGRAPHY AND PHOTOZINCOGRAPHY.

1. Hardwich. Photographic Chemistry. A manual of photographic chemistry, theoretical and practical; by T. Frederic Hardwich, late demonstrator of chemistry and lecturer on photography in King's College, London; 7th edition, edited by George Dawson, M.A., lecturer on photography at King's College; and Edward Hadow, F.C.S. Published by John Churchill and Sons, 1864. Size, 7 in. by 4¼ in. by 1¼ in. Price 7s. 6d.

2. On photozincography and other photographic processes employed at the Ordnance Survey Office, Southampton; by Captain A. De C. Scott, Royal Engineers, under the direction of Colonel Sir Henry James, R.E., F.R.S., &c. Published by permission of the Right Hon. the Secretary of State for War; Longman, 1862. Size, 12 in. by 9½ in. by ¼ in. Price 12s.

This work gives the practical details of the new art by means of which a photograph may be applied directly to a zinc plate or lithographic stone, and prints then obtained in lithographic ink.

3. Account of the methods employed for the reduction of plans by photography, at the Ordnance Survey Office, Southampton; drawn up by order of the Secretary of State for War, by Lieutenant A. De C. Scott, R.E., under the directions of Colonel James, R.E., F.R.S., Superintendent of the Ordnance Survey. This account was ordered to be written in compliance with the request of the Secretary of State for India in Council, for the information of the Officers entrusted with the superintendence of the survey in India. Printed for Her Majesty's Stationery Office by Messrs. Eyre and Spottiswoode, 1859. Size, 13 in. by 8½ in. by ¾ in.

4. Weale's Series, 79**.

PHYSICS.

1. Daguin's Physique. Traité élémentaire de physique théorique et pratique, avec les applications à la métérologie et aux arts industriels à l'usage des facultés, des établissements d'enseignement secondaires, et des écoles spéciales du gouvernement, par P. A. Daguin, ancien élève de l'école normale, professeur à la Faculté des Sciences de Toulouse, membre de l'Académie des Sciences de cette ville. 3 Vols. Published by Dezobry and E. Magdeleine, Paris 1855, 56, and 60. Size, 8½ in. by 5½ in. by 1½ in. Price £1 10s.

This work treats fully of the properties of gases, liquids, and solids; of acoustics, heat, meteorology, magnetism, electricity, optics, and light.

This is believed to be the best work on physics, but for those who prefer one in English, either of those mentioned next will be found reliable.

2. Ganot's Physics. Elementary treatise on physics, experimental and applied, for the use of colleges and schools; by Professor Ganot. Translated and edited from the 9th edition*, by E. Atkinson, lecturer on chemistry and physics, R.M. College. Published by H. Bailliere, London. Size, 8 in. by 5 in. by 2 in. Price 12s. 6d.

This work treats fully of the properties of gases, liquids, and solids; of acoustics, heat, optics and light, magnetism and electricity, and meteorology.

* An 11th edition has been published in Paris.

3. BIRD AND BROOKE. ELEMENTS OF NATURAL PHILOSOPHY; or an introduction to the study of the physical sciences; by Golding Bird, M.A., M.D., F.R.S., F.L.S., and Charles Brooke, M.A., M.B., F.R.S. Published by John Churchill; 5th edition, revised and enlarged, 1860. Size, 6½ in. by 4 in. by 1½ in. Price 12s. 6d. The print is very small.

This work treats of the properties of matter, statics, mechanical power, dynamics, pneumatics, hydrodynamics, acoustics, magnetism, electricity, light, optical instruments, chemical rays, photographs, thermetics, radiant heat. This is one of the books recommended to candidates for the examinations of the Society of Arts.

4. TYNDALL'S HEAT CONSIDERED AS A MODE OF MOTION. Being a course of twelve lectures, delivered at the Royal Institution of Great Britain, in the season of 1862; by John Tyndall, F.R.S., &c., Professor of Natural Philosophy in the Royal Institution, with illustrations. Published by Longman; 2nd edition, with additions and illustrations, 1865. Size, 8 in. by 4½ in. by 1½ in. Price 12s. 6d.

This work enters into all the properties of heat, and the doctrine of the mutual convertibility of heat and motion is fully expounded.

5. PARKINSON'S OPTICS. A treatise on optics; by S. Parkinson, B.D., Fellow and Tutor of St. John's College, Cambridge. Published by Macmillan, 1859. Size, 7½ in. by 5 in. by ¾ in. Price 10s. 6d.

6. BREWSTER'S OPTICS. A treatise on optics; by David Brewster, LL.D., F.R.S., &c., &c., being Vol. CX of Lardner's Cabinet Cyclopædia. Published by Longman, 1831. Size, 6½ in. by 4 in. by 1 in. This is recommended by the Society of Arts to candidates for their examinations.

7. Weale's Series, 2, 7, 7*, 8, 9, 10, 12, 116.

PNEUMATICS, SEE PHYSICS.

RAILWAYS, SEE CIVIL ENGINEERING.

ROADS, SEE DITTO.

ROOFS, SEE DITTO.

SMOKE, SEE DITTO.

STEAM-ENGINE, SEE DITTO.

SURVEYING, SEE DITTO AND GEODESY.

TELEGRAPHY.

1. HANDBOOK OF PRACTICAL TELEGRAPHY. R. S. CULLEY, Telegraphic engineer and superintendent; published with the sanction of the chairman and directors of the Electric and International Telegraph Company; illustrated with numerous diagrams. Published by Longman, 1863. Size, 9 in. by 5½ in. by ¾ in. Price 7s.

Extract from the preface:—"The intention of the author has been to give information to members of the telegraph service and to those interested in telegraphy, concerning the electrical laws upon which the system depends, the methods of discovering faults, the practical management of apparatus, and the construction of a line." This work is intended for land telegraphy.

2. Pamphlet on the ignition of gunpowder by electricity and on the electric telegraph; by Captain H. Schaw, R.E., formerly superintendent of the school of telegraphy at the Royal Engineer Establishment, Chatham, and printed there.

This pamphlet gives the practical and theoretical details required by an Engineer Officer for firing mines by electricity and for working a field telegraph.

3. Report of the committee appointed by the British Association on standards of electrical resistance (from the Report of the British Association for the advancement of Science for 1863). Printed by Taylor and Francis, Red Lion Court, Fleet Street, 1861. Pamphlet: Size, $8\frac{1}{2}$ in. by $5\frac{1}{4}$ in. by $\frac{1}{4}$ in.

This report gives sound mathematical information on the science of electricity generally.

4. Mr. Fleming Jenkin has written a valuable pamphlet on the retardation of signals through submarine electrical cables, and another on the retardation on land lines.

5. Weale's Series, 11, 11*.

The science of ocean telegraphy is still in a state of development, and no complete work on the subject is known. The best information is to be found in "the Report of the committee on the construction of submarine telegraph cables."

WARMING AND VENTILATION.

1. Weale's Series, 57, 58.

WATER-WORKS, see CIVIL ENGINEERING.

WEIGHTS, MEASURES, and MONEY.

1. Universal Dictionary of Weights and Measures, ancient and modern, reduced to the standard of the United States of America; by J. H. Alexander. Published by William Minifin, 1857. Size, $9\frac{1}{2}$ in. by $6\frac{1}{2}$ in. by $\frac{3}{4}$ in. Price 13s. 6d.

2. Weale's Series, 101*.

WELL SINKING.

1. Weale's Series, 31.

ZOOLOGY.

1. Jones' Organization of the Animal Kingdom. General outline of the organization of the animal kingdom and manual of comparative anatomy; by Thomas Rymer Jones, F.R.S., Professor of Comparative Anatomy in King's College, London, late Fullerman Professor of Physiology to the Royal Institution of Great Britain, &c., &c. Published by Van Voorst; 3rd edition, illustrated by 423 engravings, 1861. Size, $8\frac{3}{4}$ in. by $5\frac{1}{2}$ in. by 2 in. Price £1 11s. 6d.

Extract from the preface:—"The object of the writer of the present work has been two-fold: first, to lay before the naturalist a complete view of the organization and physiological relations of every class of living being; and secondly, to offer to the anatomical student a succinct account of the structure and development of the vital organs through all the modifications they present in the long series of the animal creation."

2. GOSSE'S MARINE ZOOLOGY. A manual of marine zoology for the British Isles; by Philip Henry Gosse, A.L.S. Published by Van Voorst, 1855-6; 2 Vols. Size, 7 in. by 4½ in. by ⅝ in. Price 15s.

This is an admirable little book of reference for all marine animals. It gives their classification from sponges up to mammalia, with a drawing of one member of every genus.

3. YARRELL'S BRITISH BIRDS. A history of British birds; by William Yarrell, F.L.S., VP.Z.S., &c.; illustrated by 535 wood engravings. Published by Van Voorst; 3rd edition, 1856; 3 Vols. Size, 9 in. by 6 in. by 1½ in. Price £4 14s. 6d.

4. YARRELL'S BRITISH FISHES. A history of British fishes; by William Yarrell, F.L.S., VP.Z.S, &c. Published by Van Voorst; 3rd edition, edited by Sir John Richardson, C.B.; illustrated by 522 wood engravings, 1859; 2 Vols. Size, 8¾ in. by 5½ in. by 1¾ in. Price £3.

These are the standard works on British birds and fishes.

WEALE'S RUDIMENTARY SERIES.

Each Vol. in demy 12mo., cloth; Size, 7 in. by 4¾ in., unless otherwise stated.

1. Chemistry, by Professor Fownes, F.R.S., including agricultural chemistry, for the use of farmers; 1s.

2. Natural Philosophy, by Charles Tomlinson; 1s.

3. Geology, by Major General Portlock, F.R.S., &c.; 1s. 6d.

4, 5. Mineralogy, with Mr. Dana's additions; 2 vols. in 1; 2s.

6. Mechanics, by Charles Tomlinson; 1s.

7. Electricity, by Sir William Snow Harris, F.R.S.; 1s. 6d.

7*. On Galvanism; Animal and Voltaic Electricity; by Sir W. Snow Harris; 1s. 6d.

8, 9, 10. Magnetism, Concise exposition of, by Sir W. Snow Harris; 3 vols. in 1; 3s. 6d.

11, 11*. Electric Telegraph, History of the, by E. Highton, C.E.; 2s.

12. Pneumatics, by Charles Tomlinson; 1s.

13, 14, 15, 15*. Civil Engineering, by Henry Law, C.E., 3 vols.; and supplement, by G. R. Burnell, C.E.; 4s. 6d.

16. Architecture, Orders of, by W. H. Leeds; 1s.

17. Architecture, Styles of, by T. Bury, architect; 1s. 6d.

18, 19. Architecture, Principles of Design in, by E. L. Garbett, architect; 2 vols. in 1; 2s.

20, 21. Perspective, by G. Pyne, artist; 2 vols. in 1; 2s.

22. Building, Art of, by E. Dobson, C.E.; 1s.

23, 24. Brick-Making, Tile-Making, &c., Art of, by E. Dobson, C.E., 2 vols. in 1; 2s.

25, 26. Masonry and Stone-Cutting, Art of, by E. Dobson, C.E.; 2 vols. in 1; 2s.

27, 28. Painting, Art of, or a Grammar of Colouring, by George Field; 2 vols. in 1; 2s.

29. Practice of Draining Districts and Lands, Art of, by G. D. Dempsey, C.E.; 1s.

30. Practice of Draining and Sewage of Towns and Buildings, Art of, by G. D. Dempsey, C.E.; 1s. 6d.

31. Well-Sinking and Boring, Art of, by G. R. Burnell, C.E.; 1s.

32. Use of Instruments, Art of the, by J. F. Heather, M.A.; 1s.

33. Constructing Cranes, Art of, by J. Glynn, F.R.S., C.E.; 1s.

34. Steam Engine, Treatise on the, by Dr. Lardner; 1s.

35. Blasting Rock and Quarrying, and on Stone, and on the Destruction of Bridges by Gunpowder, by Gen. Sir J. F. Burgoyne, Bart., &c., &c.; 1s. 6d.

36, 37, 38, 39. Dictionary of Terms used by Architects, Builders, &c.; 4s.

42. Cottage Building, Treatise on; 1s.

43. Tubular and Girder Bridges, and others, Treatise on, more particularly describing the Britannia and Conway Bridges; 1s.

44. Foundations, &c., by E. Dobson, C.E.; 1s.

45. Limes, Cements, Mortars, Concrete, Mastics, &c.; 1s.

46. Constructing and Repairing Common Roads; together with General Sir J. F. Burgoyne, Bart., on the Maintenance of Macademised Roads; 1s. 6d.

47, 48, 49. Construction and Illumination of Lighthouses; 3s.

50. Law of Contracts for Works and Services, by David Gibbons, S.P.; 1s.

51, 52, 53. Naval Architecture, Principles of the Science, by J. Peake, N.A., 3 vols. in 1; 3s.

55, 56. Navigation; The Sailor's Sea-Book. How to keep the log and work it off; latitude and longitude; great circle sailing; law of storms and variable winds; and an explanation of terms used, with coloured illustrations of flags; 2s.

57, 58. Warming and Ventilation, by Charles Tomlinson; 2 vols. in 1; 2s.

59. Steam Boilers, by R. Armstrong, C.E.; 1s.

60, 61. Land and Engineering Surveying, by T. Baker, C.E.; 2 vols. in 1; 2s.

61*. A Complete Ready-Reckoner for the Measurement of Land. A table on the price of work from 2s. 6d. to £1 per acre; with tables for the valuation of land from 1s. to £1,000 per acre; by A. Arman, schoolmaster; 1s. 6d.

62. Principles of Railways for the use of the beginner in his studies, with sketches of construction for practice; and on the permanent way, English and American; 1s. 6d.

62*. Railway Working in Great Britain; Statistical details, &c.; 1s.

66. Clay Lands and Loamy Soils, by Professor John Donaldson, A.E.; 1s.

67, 68. Clock and Watch-Making, and on Church Clocks and Bells, by E. B. Denison, M.A.; 2 vols. in 1, considerably extended; fourth edition, 3s., and the appendix, price 6d.

72, 73, 74, 75, 75*. Recent Fossil Shells (a Manual of the Mollusca); by Samuel P. Woodward; 4 vols in 1, with supplement, 5s. 6d.

76, 77. Descriptive Geometry, by J. F. Heather, M.A.; 2 vols. in 1; 2s.

77*. Economy of Fuel, by T. S. Prideaux; 1s.

78, 79. Steam as Applied to General Purposes, and Locomotive Engines, by J. Sewell, C.E.; 2s.

78*. Locomotive Engine, by G. D. Dempsey, C.E.; 1s. 6d.

79*. Atlas of Engraved Plates to Dempsey's Locomotive Engines; Royal 4to., 4s. 6d.

79**. On Photography, the composition and properties of the chemical substances used; by Dr. H. Halleur; 1s.

80, 81. Marine Engines and on the Screw, &c., by R. Murray, C.E.; 2 vols. in 1, 2s. 6d.

80*, 81*. Embanking Lands from the Sea, by John Wiggins, F.G.S.; 2 vols. in 1, 2s.

82, 82*. Power of Water as applied to drive Flour Mills, by Joseph Glynn, F.R.S., C.E.; 2s.

83. Book-Keeping, by James Haddon, M.A.; 1s.

82**, 83*, 83 *(bis)*. Coal Gas, on the Manufacture and Distribution of; by Samuel Hughes, C.E.; 3s.

82***. Water Works for the Supply of Cities and Towns; Works which have been executed for procuring supplies by means of drainage areas and by pumping from wells; by Samuel Hughes, C.E.; 3s.

83**. Construction of Door Locks; 1s. 6d.

84. Arithmetic, with numerous examples, by Professor J. R. Young; 1s. 6d.

86, 87. Algebra, by James Haddon, M.A.; 2 vols. in 1, 2s.

88, 89. Elements of Geometry, by Henry Law, C.E.; 2 vols. in 1, 2s.

90. Geometry, Analytical, by Professor James Hann; 1s.

91, 92. Plane and Spherical Trigonometry, by the same; 2 vols. in 1, 2s.

93. Mensuration, by T. Baker, C.E.; 1s.

94, 95. Logarithms; Tables for facilitating astronomical, nautical, trigonometrical, and logarithmic calculations; by H. Law, C.E. New edition, with tables of natural sines and tangents, and natural cosines; 2 vols. in 1, 2s. 6d.

96. Popular Astronomy, by the Rev. Robert Main, M.R.A.S.; 1s.

97. Statics and Dynamics, by T. Baker, C.E.; 1s.

98, 98*. Mechanism and Practical Construction of Machines, by T. Baker, C.E., and on Tools and Machines, by James Nasmyth, C.E.; 2s. 6d.

99, 100. Nautical Astronomy and Navigation, by Professor Young; 2 vols. in 1, 2s.

100*. Navigation Tables compiled for practical use with the above; 1s. 6d.

101. Differential Calculus, by Mr. Woolhouse, F.R.A.S.; 1s.

101*. Weights and Measures of all Nations: Weights, coins, and the various divisions of time, with the principles which determine rates of exchange; by Mr. Woolhouse, F.R.A.S.; 1s. 6d.

102. Integral Calculus, by H. Cox, M.A.; 1s.

103. Integral Calculus, Examples of; by Professor James Hann; 1s.

104. Differential Calculus, Examples of; by J. Haddon, M.A.; 1s.

114. On Machinery: Rudimentary and elementary principles of the construction and on the working of machinery; by C. D. Abel, C.E.; 1s. 6d.

115. Atlas of Plates to the above; Royal 4to., 7s. 6d.

116. Treatise on Acoustics: The distribution of sound; by T. Roger Smith, architect; 1s. 6d.

117. Subterraneous Surveying, Ranging the Line without the Magnet, by Thomas Fenwick, coal viewer; with improvements and modern additions by T. Baker, C.E.; 2s. 6d.

118, 119. On the Civil Engineering of North America, by D. Stevenson, C.E; 2 vols. in 1, 3s.

120. On Hydraulic Engineering, by G. R. Burnell, C.E.; 2 vols. in 1, 3s.

121. Treatise on Rivers and Torrents, from the Italian of Paul Frisi; 1s. 6d.

122. On Rivers that carry Sand and Mud, and an Essay on Navigable Canals; by Paul Frisi; 121 and 122 bound together, 2s. 6d.

123. On Carpentry and Joinery, founded on Dr. Robison's Work; 1s. 6d.

123*. Atlas of Plates in detail to the carpentry and joinery; 123 and 123* bound together in cloth in 1 vol.; demy 4to., 4s. 6d.

124. On Roofs for Public and Private Buildings, founded on Dr. Robison's Work; 1s. 6d.

124*. Recently Constructed Iron Roofs, Atlas of plates; Royal 4to., 4s. 6d.

125. On the Combustion of Coal and the Prevention of Smoke, chemically and practically considered; by Charles Wye Williams.

126. Illustrations to William's Combustion of Coal; 125 and 126, 2 vols. bound in 1, 3s.

127. Practical Instructions in the Art of Architectural Modelling; 1s. 6d.

128. The Ten Books of M. Vitruvius on Civil, Military, and Naval Architecture; translated by Joseph Gwilt, architect; 2 vols. in 1.

129. Illustrative Plates to Vitruvius's Ten Books, by the Author and Joseph Gandy, R.A.; 5s.

132. Treatise on the Erection of Dwelling Houses, with specifications, quantities of the various materials, &c., by S. H. Brooks, architect; 27 plates, 2s. 6d.

On Mines, Smelting Works, and the Manufacture of Metals, as follows.

Vol. 1. Treatise on the Metallurgy of Copper, by R. H. Lamborn; 2s.

Vol. 2. Treatise on the Metallurgy of Silver and Lead; 2s.

Vol. 3. Treatise on Iron Metallurgy up to the manufacture of the latest processes.

Vol. 4. Treatise on Gold Mining and Assaying Platinum, Iridium, &c.

Vol. 5. Treatise on the Mining of Zinc, Tin, Nickel, Cobalt, &c.

Vol. 6. Treatise on Coal Mining (Geology and means of discovering, &c.)

Vol. 7. Electro-Metallurgy, practically treated by Alexander Watt, F.R.S.A.; 1s. 6d.

Chronology of Civil and Ecclesiastical History, Literature, Art, and Civilisation, from the earliest period to the present; 9, 10, 2 vols., 2s. 6d.

Dictionary of the English Language; 12, 13. A new Dictionary of the English Tongue as spoken and written, above 100,000 words, or 50,000 more than in any existing work; by Hyde Clarke, D.C.L.; 3 vols. in 1, 3s. 6d.

Dictionary of the Greek and English Languages; 15, 16; by H. R. Hamilton; 2 vols. in 1, 2s.

Dictionary of the English and Greek Languages; 17, 18; by H. R. Hamilton; 2 vols. in 1, 2s.

Dictionary of the Latin and English Languages; 20, 21; by the Rev. T. Goodwin, B.A.; Vol. 1, 2s.

Dictionary of the English and Latin Languages; 22, 23; by the Rev. T. Goodwin, B.A.; Vol. 2, 2s.

Dictionary of the French and English Languages; 25; by A. Elwes; Vol. 1, 1s.

Dictionary of the English and French Languages; 26; by A. Elwes; Vol. 2, 1s. 6d.

Dictionary of the Italian, English, and French Languages; 28, 29; by A. Elwes; Vol. 1, 2s.

Dictionary of the English, Italian, and French Languages; 30, 31; by A. Elwes; Vol. 2, 2s.

Dictionary of the French, Italian, and English Languages; 32, 33; by A. Elwes; Vol. 3, 2s.

Dictionary of the Spanish and English Languages; 35, 36, 37, 38; by A. Elwes; 4 vols. in 1, 4s.

Dictionaries of the English, German, and French Languages; 41, 42, 43; by N. E. Hamilton, 3 vols., separately, 1s. each.

A. C. C.

PAPER XI.

REPORT

UPON

CONCRETE REVETMENTS,

BUILT AT NEWHAVEN FORT.

By LIEUTENANT ARDAGH, R.E.

[Inserted by permission of the Director of Works.]

Newhaven Fort is situated at the mouth of the River Ouse, on the western side. Its sea-face rests on a cliff from 120 to 140 feet high, at the foot of which has accumulated a large mass of shingle, the joint consequence of the prevailing south-westerly winds, and of the groynes and piers of the harbour. From the facility with which shingle could be obtained, it was determined that concrete should enter extensively into the construction of the work. The concrete for the revetments has been made in accordance with the following specification:—

"The revetments are to be of concrete, composed of one part of Scott's cement, one part of coarse, clean, sharp sand, and six parts of ballast shingle or flint, mixed properly dry; a sufficient quantity of water to be added just before, and as it is required for the works: to be laid in courses 1 foot high, and rammed as laid to form the wall, care being taken to prevent large stones from running to the front; and a shovel to be worked up and down between the front of the concrete and the boarding which supports it, so as to bring the mortar to the face. Each of the 12-inch layers to be allowed a sufficient time to harden before another is put on, and in no case shall more than three layers be allowed to follow before the under portions shall have become perfectly hard and consolidated. The fitness for the recommencement of the work in each case to be decided by the superintending officer."

"The contractor to provide all the necessary boarding for the face of the wall, which is to be fixed to such lines, slopes, or batter, as may be required; and it is presumed that sufficient boarding to raise the wall three feet high is all that will require to be fixed at one time, care being taken that the lower edge, or starting, upon the last layer, shall, in all cases, be well secured and neatly fixed, so as not to show an offset on the face of the wall."

"The rear face of the concrete is also to be retained by boarding or other filling, to retain it to the required section."

"Provision is to be made in constructing the concrete and other walls of ditches, for forming apertures where directed to remove superfluous water from behind walls with common 3-inch agricultural pipes, jointed in cement, and projecting 3 inches over face of wall."

"The Scott's cement is to be finely ground, to contain not less than 10 per cent. of soluble silica, to weigh at least 60 lbs. per striked bushel, [filled into a measure as lightly as possible] and to bear the following test, viz, when mixed with two measures of sharp washed sand to one measure of cement, and moulded into the form shown in the annexed sketch, (see Pl. II.) it is to form a sufficiently coherent mass in 24 hours, to allow of its removal from the mould; and when a block so made has been exposed to the air in a dry place for seven days (from the time of mixing), it is to support a longitudinal strain of not less than 65 lbs."

The Scott's cement is obtained from Messrs. Rickman's manufactories at Glynde, near Lewes. The result of the tests of 153 specimens, made from 29 lots of cement in 1865, gives the following table:—

	Mean Maximum	Mean Mean.	Mean Minimum.
Absolute breaking weight	134	117	100
Breaking weight in lbs., per sq. in.	60	52	44

The greatest breaking weight recorded was 108 lbs. per sq. in., and the least was 13 lbs. per sq. in., when 7 days old.

Materials.	Weight per cubic foot in lbs.	Tenacity per sq. inch in lbs.
Brick in mortar	100	50
Concrete in Scott's cement.	140	120
Rammed backing	100	...

The foregoing table shows that the concrete in question is far superior to brickwork as a material for the construction of retaining walls, being 40 per cent. heavier, and more than twice as strong.

The section (Pl. II.) shows the form of revetment adopted, and the average nature of the soil. Assuming the natural slope of the ground to be 30°, that is to say, under the most unfavourable circumstances which could occur, the ratios of the moments of the weight of the revetment, and of the maximum pressure of the earth, round the toe of the revetment, are: for the escarp, 4 to 1; for the counterscarp, 6 to 5. Wherever the loam extends nearly the whole depth, the counterscarp has been strengthened in its counterforts.

The work is executed in the following manner. To raise the shingle from the beach, a lift composed of scaffolding poles lashed together, with the usual ledgers and braces, was erected at a point of the cliff 120 feet above the beach, and secured by guys and stays of chain. (Pl. I.) The face of the scaffolding has two vertical barrow slides, with overhead pulleys and hoisting chairs, which below are led to a drum 26 inches in diameter, worked by a 12-horse engine.

The barrows, which have additional ledges to increase their capacity, are filled, wheeled to the foot of the lift, hoisted, and wheeled away, at the rate of fifty per hour. Each contains $\frac{1}{8}$th of a cubic yard. In this manner $62\frac{1}{2}$ yds. per diem are raised a height of 125 feet, and wheeled an average distance of 400 feet, at the net cost of 1s. 6d. per yard.

From the heap which is accumulated in this manner, the shingle is carted or wheeled to whatever parts of the work it may be required.

The concrete is mixed on a platform of plank, and wheeled to its position, where it is distributed and rammed.

The face of the revetments is thus formed. Standards, 30 ft. by 9 in. by $4\frac{1}{2}$ in., are ranged 12 ft. apart, and 6 in. clear of the intended face of the revetment. Each piece of boarding is composed of three or four 12-inch deals, wrought on one side and edges, bolted through and ledged at the back, with a staple, ring, and rope at each end to attach it to the standards.

These boards are wedged up into their exact position from the standards, which are strutted, or, when the work becomes high, are tied to the revetment by wires or pieces of hoop iron, which are subsequently cut off flush with the face. A rougher system is adopted for the back. By this means a perfectly uniform and fair surface like that of rubbed stone can be obtained, and when the work is continuous, the joints are hardly perceptible. At first great difficulty was experienced in exacting the necessary care. The chief points which require attention are: that a sufficiency of sand should be used; that the concrete should be thoroughly mixed; that the boarding should be perfectly smooth and plane; and that the ramming be well done. This last has been a chronic source of annoyance.

An average of one layer per diem may be attained, but not more than three should be put on in the same day, and that only in very dry hot weather.

The economy of using concrete instead of brickwork is very great. In the case of Newhaven, the contract price of brickwork, per rod, is £8 5s. That of concrete, in Scott's cement, is, per yard, 5s. 10d., or £3 6s. per rod. When the additions for labour to faces, cuttings, splays, pointing, etc., are made to the brickwork, its cost is raised to nearly three times as much as the concrete.

The north ditch of the work lies nearly east and west (Pl. I.) The counterscarp on this face was commenced in March, 1865, and the escarp in June.

In the middle of November, the face of the counterscarp began to show slight vertical cracks, which gradually increased, and the cause and history of which present considerable interest.

It was reported on the 29th November, 1865, that there were in the counterscarp three vertical cracks, the largest being under $\frac{1}{16}$th of an inch in width; and in the escarp, one vertical crack $\frac{1}{16}$th of an inch wide. These cracks might have arisen from various causes:—

1st. Faulty design, or natural pressure at back.

2nd. Construction.

3rd. Subsidence of foundations.

4th. Change of temperature.

With respect to the first possible cause, I have already mentioned that the section appeared to be sufficiently strong; and, moreover, cracks arising from horizontal thrust are always accompanied by displacement or bulgings, of which there was no sign.

As to the second, the tests which have been made from time to time, and previously mentioned, together with the appearance of the wall, are a sufficient guarantee.

The third cause most frequently gives rise to horizontal cracks, and if vertical cracks appear, they always show vertical displacement: there were no such indications, the separation of the particles having taken place in a direction perfectly horizontal, and the wall remaining in its original plane. The fact of the foundation being on solid chalk almost precludes the possibility of this cause coming into operation.

The fourth—change of temperature—is a subject which has not been treated with much attention as regards its effect on buildings and building materials; indeed there is very scant information, and that, principally, in scientific and philosophical records. (See note at end of paper.)

The following table, based on Greenwich observations, indicates the rate of progress of the annual wave of temperature at different depths below the surface.

No.	Depth of bulb of Thermometer below surface.	Maximum mean monthly reading.		Minimum mean monthly reading.		Annual range.
1.	1 inch.	July,	67°	January,	37°	30°
2.	3·2 feet.	August,	62·3	January,	39·3	23
3.	6·4 "	August,	58·9	February,	42·8	16
4.	12·8 "	September,	55·1	March,	45·8	9
5.	25·6 "	January,	52	May,	48·8	3

It appears from this table that the soil, at a depth of from 12 to 25 feet below the surface, would be at its minimum temperature during the months of March, April, and May, at which season the excavations were completed, and the foundations of the revetments laid; and at its maximum temperature, between September and January, when the cracks appeared; the range of temperature being between 3° and 9°.

The concrete was put in during an unusually hot summer at a temperature exceeding 60°. In November, after seven weeks cold and wet weather, it fell to 45° or less. The earth had risen in temperature 6°, the concrete had fallen 15°, and the process might be expected to continue until January, when the concrete would be reduced to 39°, and the earth raised to 52°.

The coefficients of linear dilatation of such materials as it has been possible to procure information of, are as follow, for a change of temperature of 180° F.:—

Brick	·0005
Granite	·0009
Slate	·0010
Roman cement	·0014

Although there is reason to believe that the concrete in question has a greater coefficient than any of the above-mentioned materials, it is assumed for the present to equal that of slate (viz., ·001).

The change in length of a portion of the revetment, 20 feet long, due to an alteration of 15° in temperature, would be

$$20' \times 12'' \times 15^\circ \times \cdot 001 \times \frac{1}{180^\circ} = \cdot 02'' \text{ or } \tfrac{1}{50}\text{th. of an inch.}$$

This, which is equivalent to a tenth of an inch in every hundred feet, is amply sufficient to account for all the cracks.

It must be observed that the counterscarp of the north ditch faces the south, and is consequently open to extremes of temperature; while the escarp facing the north was protected from the sun's rays by the parapet in rear of it, except in one place, where, on account of a considerable depression, it was exposed to the sun; in that place alone it cracked.

The foregoing conclusions were embodied in a report on the 29th November, 1865, when, from these data, it was anticipated that a further increase in the number and dimensions of the cracks would take place during the two following months, and that many would close during the succeeding summer, but that the action of weather, dirt, and debris would eventually make the cracks larger.

It was recommended that no steps should be taken to remedy the defect, but that subsequently the wall might be cut through at some of the points of fracture, and dry-tongued brickwork built on each side to allow of a movement which it would properly be impossible to prevent.

On the 17th April, 1866, it was reported that the anticipations of November were realized.

Tell-tales of cement pointing and gauges (Pl. II.) had been attached to the wall at several of the larger cracks, and were observed from time to time. The cracks increased in magnitude until the end of January, when the tell-tales were broken, and the gauges indicated an expansion of $\frac{1}{20}$th part of an inch. From that time they contracted, and in April were from $\frac{1}{40}$th to $\frac{1}{30}$th part of an inch narrower than in November; many, consequently, had altogether disappeared.

It was believed that the larger ones would in a few months be almost invisible. August has now arrived, and the largest of the cracks is not broader than a hair; but for the gauges and the pointing with which the contractor's workmen thought to remedy the defect, they would scarcely be visible.

There appears to be no doubt that the theory proposed to explain their origin, though it at first met with many sceptics, is substantially correct; and it is expected that as the autumn advances the cracks will again become apparent, and the process will be repeated.

It will not often happen that a wall may be built under similar circumstances to the counterscarp at Newhaven, where all the conditions conspired to exaggerate the effects of temperature. Had the revetment been commenced in November, built slowly, and filled in behind as it was raised, the cracks would have been very minute, though not altogether absent.

A fall of temperature of 10° will shorten a stone wall 100 feet long, by $\frac{1}{18}$th of an inch. From the temperature table already given, it is obvious that such a differential change must take place if the foundations are 5 feet deep, for the annual ranges will be for the upper part of the wall 30°, and for the lower 20°. If such a wall does not crack, its elasticity must be inconceivable.

The alterations in distance on the earth's surface, caused by change of temperature, appear quite sufficient to account for discrepancies between different measurements of the same base. Those engaged on geodetical operations have yet to consider this element of error, which, though small, would be almost impossible to correct.

In future works, where walls of concrete are exposed to considerable variations of temperature, it would appear desirable to adopt a design which would either allow of expansion and contraction, or, at least, ensure the cracks appearing in positions which may be assigned to them. The dry joint would allow of the former, and the pier and panel principle of the latter. (See Pl. II.)

Ashlar and brick walls have been observed to crack, but the blame which is almost invariably laid on the foundations, is probably due to change of temperature.

Many instances doubtless exist when this could be ascertained by applying gauges to the cracks, and measuring them monthly for a year, or, in a more rough way, by tell-tales of cement. It is a matter of ordinary experience that concrete walls usually crack vertically, and it would be interesting to ascertain the precise amount of linear dilatation caused by change of temperature, and whether the use of different materials in its composition has a marked influence on the coefficient.

J. C. A.

Royal Engineer Office,
Newhaven Fort,
28th July, 1866.

Note to Report on Concrete Revetments.

Since the above-mentioned Report was forwarded, the writer has seen a paper in Les Annales des Ponts et Chaussées, (No. 50, Vol. II, 1863) entitled EXPÉRIENCES *sur la dilatation des maçonneries;* par M. BOUNICEAU, Ingênieur-en-Chef des Ponts et Chaussées.

The following is an extract:—

"Some unimportant fissures which appeared during the winter of 1859-60, in certain parts of the work at the port of Havre, caused us uneasiness during some days, for we attributed them to an unequal settlement of the foundations, to the extent of which we could assign no limit. After a long examination, we remarked that the most characteristic fissure existed in a wall uncovered on both faces, and in which inequality of settlement was inadmissible. This happened in the winter, at a temperature of 10° Fah., and the masonry had, for the most part, been recently built, in the summer of 1859, during an exceptionally high temperature of 80° Fah. We then began to hope that the fissures were due to contraction caused by cold."

The report then proceeds to describe the manner in which experiments on the dilatation of building materials were carried on, and the results arrived at are contained in the subjoined table.

Coefficients of dilatation of building materials for a change of temperature of 180° Fah. (100° Cent.) :—

No.	Material.	Coefficient.
1.	Pure Portland cement	·0010
2.	Mortar (2 sand, 1 Portland cement).........	·0012
3.	Brickwork (all stretchers)	·0009
4.	Brickwork (all headers)	·00045
5.	Concrete (shingle and Portland cement)...	·0014
6.	Limestone (oolitic)	·00075
7.	Granite	·00085
8.	Marble	·00054
9.	Plaster of Paris (gypsum)	·0016

In his subsequent observations, M. Bouniceau corroborates the general conclusions detailed above.

It will be observed that the coefficient assumed for concrete (·001) was rather too small.

J. C. A.

20th September, 1866.

PAPER XII.

ON THE NEW WORKS OF FORTIFICATION AT ANTWERP.

By CAPTAIN SCHAW, R.E.

A brief description of the new Fortifications at Antwerp has been given by Lieut. Colonel Grattan, R.E., in Vol. XIII of these papers, page 73. The present paper is intended as a supplement to that description, which referred more to the method of constructing the works than to the details of the works themselves.

My visit to Antwerp was made in June, 1865. A letter of introduction to Lieut. Colonel Brialmont, with which I was furnished by Col. Jervois, C.B., R.E., obtained for me at once a pass for viewing the works, and letters of introduction to the Engineer Officers in charge of them.

My acknowledgments are due to Lieut. Colonel Brialmont and the Officers of the Belgian Engineers, who were most courteous and obliging in shewing me the drawings of the works, and affording me the fullest information. Lieut. Colonel Brialmont also was good enough to allow me to trace a drawing which he had made for the Belgian Military School, being the type on which the main fronts of the enceinte have been constructed. A copy of this tracing was made by Captain Philips, R.E., and lithographed for the course of fortification, which he has lately drawn up for the Cadets of the Royal Military College; a sufficient number of extra copies have been secured for this paper.

Before describing the works it will be well to review briefly their objects. In the "Reports relating to the re-establishment of the Fortresses in the Netherlands, from 1814 to 1830;" edited by the late Lieutenant General Sir H. D. Jones, K.C.B., will be found an account of the system of defence which the Duke of Wellington recommended in 1814, and which was adopted and carried out under his direction.

Political circumstances, and changes in the art of war, which have since occurred, have led to the abandonment of that system of defence, and to the concentration of the defensive power of the Kingdom of Belgium, mainly in and around Antwerp, its commercial capital.

Brussels, being the seat of government, would seem the more natural position for the great central fortress of the kingdom; but the configuration of the ground in the vicinity is peculiarly unfavourable for such a purpose, and the difficulty of preserving the communications of Brussels with friendly powers (it is presumed that England and Holland would be allies) would be so great

that Antwerp was selected in preference. The only other fortified places retained in the new system of Belgian national défence, are the fortresses of Diest and Termonde; the citadels of Ghent, Tournai, Namur, and Liège; and a fort at the last-named place. The view taken by the Belgian Government being, that a small state cannot hope to withstand the overwhelming force of its great neighbours in the field, and that consequently a number of small fortresses on the frontier are of no value, as their garrisons diminish the main army, and the invaders could easily mask them and pass them by. The war establishment of the Belgian army consists of 100,000 men, of these it is considered that 18,000 would suffice to guard the Antwerp position against a coup-de-main, leaving the bulk of the army free to act in the open field, with the support of the few fortresses which have been retained. If overpowered by the invaders, the army would retire upon Antwerp, of which the defences are arranged so as to constitute an immense entrenched camp, and here they would maintain a struggle for the independence of the kingdom under the most favourable circumstances possible, the communications with friendly powers being maintained by the sea.

An accurate plan of the fortifications and ground in the vicinity of Antwerp has been made by the Dutch Government, and may be purchased at the Hague (or in England through a foreign bookseller), for a few shillings, it is entitled, Plan, feuille No. 55 (de Hulst) de la Carte de la Hollande, échelle $\frac{1}{50000}$. Gravé en 1863 à la Haye.

The plans and sections of the detached forts may be found in Brialmont's "Études sur la défense des États, et sur la Fortification." Atlas; Plates XI, Fig. 1, and XV, Figs. 1, 2, 3. The only important correction necessary being that the ditch of the keep is dry.

The two fronts of the great enceinte facing to the south-east, at the village of Berchem, have advanced lunettes intended to facilitate sorties and to strengthen this portion of the line, which, from its saliency and the favourable nature of the soil, is most liable to attack. The prolongations of the general line of the enceinte on either side of these two fronts fall upon these advanced lunettes. Their details are given in Plate XXVII, Figs. 2 and 3, of Colonel Brialmont's work above alluded to.

The front of the enceinte taken as the type, and shewn in the Plate illustrating this paper, is that on the right of the line, at St. Laurent, connecting the fronts having advanced lunettes, with the line which ends the enceinte on the right, and is flanked by the old citadel.

The cavalier, at the left extremity of the front, serves the double purpose of flanking the advanced lunettes on its left, and of obstructing the enfilade fire which might be brought to bear upon the front. The three fronts forming nearly a straight line facing eastwards, between Berchem and Deurne, are almost identical with that at St. Laurent; there is a cavalier at Berchem similar to that on the left of the St. Laurent front, and intended to perform similar duties.

The remaining four fronts between Deurne and the North Citadel are of the simplest possible trace: a rampart and broad wet ditch, flanked by caponiers, having 7 guns in casemates on each side, and similar in trace to those defending the fronts of the detached forts, except that they have open courts.

The North Citadel is a simple polygon of seven sides, varying from 350 to 500

metres in length, having a broad wet ditch defended by four caponiers armed with artillery.

This citadel, and the four simple fronts adjoining it, are provided with a covered way and an advanced wet ditch, and they can be further covered by an extensive inundation in case of attack.

Each of the principal fronts consist of the following parts, viz., a *defensible barrack* capable of containing 1,200 beds, two *curtains*, two *first flanks* defending the ditch at the head of the *caponier*, two *second flanks* defending the *terreplein in rear of the caponier*, two *faces*, and two *orillons;* the space in rear of each orillon is called the *place of assembly.*

The *caponier* is composed of two *flanks*, a *head*, and two *wings*. The *low flanks* are casemated, the *high flanks* are open. The primary use of the wings is to serve as counterguards to the head of the defensible barrack.

The *couvreface* is composed of two *branches*, and of a *crenellated counterscarp gallery* from which the galleries of the countermines radiate. At the foot of the couvreface is a palisade or a demi-revetment of 3·5 metres in height, the foundations of which descend below the water level.

The *ravelin* is composed of two *branches*, composed each of two *crochets* and of a *reverse battery*, under which are bombproofs for the guard of the ravelin.

The *large traverses* of the body of the place and of the ravelin have bombproofs for the moveable artillery on the ramparts, and the gunners serving these pieces.

The geometrical construction for the trace is as follows, viz.:—

Bisect AB, the exterior side* (which varies from 900 to 1,100 metres), and erect a perpendicular; make CD equal to 95m., and CP = 65m.; through P draw PQ parallel to the exterior side and = 115m.; join DQ and draw QR perpendicular to DQ and = 31·5m.; through R draw RG parallel to the capital of the front and make RS = 11m.; at 25m. from Q erect a perpendicular to PQ, which, by its intersection with DQ, determines the point O′. The point O is determined by drawing a parallel to the curtain through the middle point of the second flank RS. The head of the defensible barrack FU must be within the line of fire grazing the extremity of the orillon L, and the point O of the wing of the caponier.

To trace the wing of the caponier make CC′ = 20m., and $G'' G' = \frac{1}{3} G'' G$, and join C′ G′. The court of the caponier is 16 metres wide at C′, and is 70 metres long, it is 10 metres wide at the outer extremity.

The point I, terminating the masonry counterscarp of the caponier, is found by the intersection of DG with a line parallel to DQ at 18m. distant from it.

To trace the couvreface of the caponier make CE = 165m., and CH = 175m.

To trace the ravelin make CF = 270m. and CI = 225m. The tracing line LK of the orillon is obtained by joining D with the first pier of the casemated battery of the first flank.

The remainder of the construction may be observed by inspecting the drawing in which the following slight errors are to be observed:—

1. There should be 14 embrasures in each low flank of the caponier instead of 15.

* When two exterior sides occur in the same straight line, or nearly so, one is given a sufficient brisure inwards to ensure that the caponiers shall not fire into one another.

2. The letter Q should be added at the point of junction of the curtain with the first flank.

3. The embrasures on the face of the body of the place, to the right and left of xy, should be traced more obliquely, so as to flank the ditches of the couvreface and of the ravelin respectively.

4. The faces of the cavalier are about 8 metres too long, and the three embrasures should be traced so as to allow of a more divergent fire.

5. The low batteries flanking the ravelin do not quite correspond, and their courtyards (particularly that on the left) are rather too small.

The figured reliefs upon the plan and the profiles, give much information as to the details of a front; but some further explanation and observations may be interesting.

Reliefs. The site is very nearly level, and the command of the enceinte is most imposing. The plunging fire from the rampart upon the nearer approaches of a besieger, would render it most difficult to defilade the trenches.

Direct fire. The whole of the ramparts can be utilized for direct artillery fire, as the command over the outworks is very considerable. The outworks are also arranged so as to give a powerful fire in the direction of the capital, in addition to cross, flanking, and reverse fire.

Ditches. The wet ditches are broadest at the salients, in order to present a more formidable obstacle to an enemy at the point where he would probably endeavour to cross; they are from $2\frac{1}{2}$ to 3 metres deep, and the sluices are protected by the citadels. The dry ditch of the couvreface is useful as a covered position for the defenders of the ravelin, and facilitates the recapture of that work should it be taken.

Flank defence. Each ditch is flanked by a double tier of guns, of which the lower tier is in casemates, and the upper tier in an open battery. The longer the line of defence, the more guns are provided to sweep it; some being intended to fire case point blank, others shrapnel and shells, with the necessary elevation.

Casemated batteries. All the casemated batteries are masked by earthen merlons in front à la Haxo. The thickness of earth is usually 6 metres. The embrasures in the earth are revetted with large gabions. The merlons appear weak, owing to the small distance between the embrasures (ordinarily 5 metres from centre to centre), but in time of war every alternate embrasure would be filled with earth, and only half the guns used; at night an injured embrasure could be masked and its neighbour opened. In peace time all the embrasures are left open for light and air.

Revetments. The escarps and counterscarps are both unrevetted, except the curtains and the heads of the caponier, and defensible barracks, and these are all counterarched and completely masked from the view of an enemy, although the upper story of the head of the barrack might be injured by curved fire. The obstacle to be overcome is the broad wet ditch.

Earthen slopes and berms. All the earthen slopes exposed to an enemy's fire are at the inclination of $\frac{2}{1}$; the slopes of escarp and counterscarp at $\frac{3}{2}$. The broad berms are required to support the great masses of earth, and they give great facilities for repairs.

Covered way. The usual traverses are omitted, because they afford cover to an enemy from the fire of the place; the crotchets and the large traverses at the salient and re-entering places of arms, protect the defenders in great measure from enfilade fire. Blockhouses are intended to be constructed in time of war at WW.

Ravelin. The principles of Choumara are here carried out, the parapet being traced independently of the scarp line, so as to give a fire to the front, and to be but little exposed to enfilade fire. The casemated battery for reverse fire at the salient is also his, and would doubtless have a powerful influence in retarding the attack on the adjacent ravelins; its massive head protects the embrasures from distant fire.

Couvreface. The main object of this is to cover the caponier and the communications across the main ditch; but the battery at the salient, and the countermines radiating from it, would assist materially in the close defence or recovery of the ravelin.

Low batteries. These defend the ditch of the ravelin. They are attached to the ravelin, and a court in rear is closed by a loophole wall. They act also as Reduits to the re-entering places of arms, and defend the drawbridges which adjoin them, and which are arranged so as to roll under the guard-rooms situated in these works. The vaulted roofs of these batteries are not masked with earth, the object being to give them the minimum relief so that the fire from the ramparts in rear may strike the ditch as near to them as possible. The danger of the roofs being destroyed, is of course an objection to this construction, but the roof is a small target for mortar practice.

Caponiers. The heads of the caponiers are solid, and the piers of the counter-arched revetment extend far inwards to increase the resistance to breaching. The open court is considered preferable to an arched passage down the centre, as the casemates are lighter and more airy, and therefore better both for barracks and for the service of the guns.

It is intended to use splinter proof blindages, or low walls closing the ends of the casemates, to protect them from vertical fire; the reverse of the casemates can be used as mortar batteries if required.

The Engineer officer who shewed me the plans of one of these works, remarked that the casemates ought to have been wider to make good barracks, as they will not allow a passage between two rows of beds with their heads to the piers of the arches.

Barbettes and vaulted traverses. The long barbettes for moveable artillery and vaulted traverses to to receive the guns and gunners when not required to fire, are novel features which are fairly open to criticism. The arrangement appears to be good for the early stage of the attack before the enemy's batteries are established, and also at the end of a siege to repel an assault; but probably nothing except iron shields, or a system of raising and lowering guns to fire over a parapet, will meet the requirements of the attack and defence of a fortress when rifled guns are used on both sides.

Defensible barracks. The defensible barrack is loopholed for musketry, and carries artillery on the vaulted roof which constitutes a cavalier. The flanks of the barrack sweep the ramparts on either side. This structure is

not an essential part of the fortifications, and at the time of my visit only one had been undertaken, owing to a want of funds.

Bombproofs. In addition to the defensible barrack, the caponier, the low batteries, and reverse battery of the ravelin, and the casemates of the 1st and 2nd flanks, there are extensive bombproofs under the curtains, the orillons, and the wings of the caponier. The whole fortress will have bombproof accommodation for about 25,000 men, besides magazines and stores.

Communications. The defensible barrack is separated from the curtain on each side by a passage 8 metres wide; small drawbridges at these points lead to the caponier and arched passage through its head, and drawbridges across its ditch lead to the couvreface and other outworks; but the main roads out to the front are through arched passages under the curtains 8 metres wide, over two drawbridges of the same width, and along causeways, 10 metres wide, across the main ditch, when they turn to the right and left skirting the counterscarp, and crossing the ditch of the reduit of the re-entering place of arms by another drawbridge, and so out through a cutting in the glacis. These roads are well protected from an enemy's fire, but are swept by all the flanking guns of the enceinte. They are practically level, and as direct as possible, and they pass *through* no outwork. They seem, therefore, exceedingly well designed for facilitating powerful sorties.

The draw-bridges are all rolling bridges, the larger bridges being made in two parts; all the communications with the ramparts are by broad ramps, except with the high flanks of the caponier, which are reached by stairs in rear of the wings.

2nd flanks. The object of these flanks is to defend the terreplein in rear of the caponier; the floors of their casemates are at the level 11·50m. or $2\frac{1}{2}$ metres above the level of the place of assembly, hence the guns being considerably depressed would not fire into one another. These casemates are not masked with earth in front, but they are completely protected by the orillons.

Whatever slight defects may be considered to exist in the new enceinte of Antwerp, it must be allowed that it presents the most perfect type of polygonal fortification adapted to a wet site that has yet been designed; and it is exceedingly difficult to suggest a plan of attack by which such a place, resolutely defended by an adequate garrison, might be reduced by regular siege. It is, however, brought as an objection against the whole scheme, that were the line of detached forts once forced, and a siege commenced against the enceinte, batteries of rifled guns could be established sufficiently near to the town and shipping to destroy them, and thus gain the ultimate object of the attack without absolutely taking the place. Until the projected forts are constructed to the north-west, on the left bank of the Scheldt, a bombardment from that side seems also possible, notwithstanding the inundations, which do not extend far enough to prevent the establishment of batteries within bombarding distance.

As regards the detached forts, they appear thoroughly well calculated to fulfil their object. They are large and important works, having each an armament of 120 guns and 15 mortars, and requiring a garrison of 1,000 men. The flanking caponiers are so well covered from distant fire, and the forts are of such strength at the gorge, that hasty attacks, either by a previous bombardment and then

an attack in force, or an attack by surprise, seem equally hopeless. A regular siege of at least two forts would therefore appear to be necessary, and if they are supported by an army in the field and by powerful intermediate batteries, as is intended, such an operation would be attended with immense difficulties, as history bears ample witness. The peculiarities of these forts, which seem also excellencies, are as follows :—The massive head to the front caponier, acting as an attached couvreface, protects at least two or three guns on each side until the end of the siege. The glacis covering the masonry of the keep in front, and the redan covering it in rear, effectually preserve it intact, until the moment when it may be required, at the end of the siege of the fort. The long Haxo casemates, and massive traverses on the flanks, and the parapet broken à la Choumara, seem well designed to preserve the guns from enfilade fire.

The bombproofs under the rampart of the front face which will admit a field battery of 8 guns, fully horsed and equipped, to take shelter during a bombardment, is a novel and ingenious arrangement. The barbettes are of more doubtful value, but they can easily be altered during a siege, and embrasures formed if found necessary. The cupola on the keep appears calculated to increase materially the power of resistance of the fort.

The guns intended for the defence of these works are cast-iron 24-prs. and 12-prs. rifled, and throwing elongated shells weighing about 64 lbs. and 20 lbs. They are breech-loaders, and the metal is of such excellent quality that they are said to answer well without any strengthening.

H. S.

August 18th, 1866.

PAPER XIII.

SHORT SUMMARY OF THE CAMPAIGN IN AUSTRIA OF 1866.

By LIEUT. COLONEL COOKE, R.E.

With sketches and description of the battle-field of Sadowa, by Capt. Webber, R.E.

The recent Prussian campaign against Austria has exemplified the saying of the first Napoleon, "Rien réussit comme le succès." There is no doubt that the first rough test applied by lookers-on to military operations is that of success, and it is perhaps to a certain extent excusable, for in war much depends on moral causes, such as the talent of the opposing General, the spirit of the troops, the temper of the inhabitants, &c., which are not, so to speak, commensurate with material causes, and a due appreciation of which can often only be tested by success. In war also, much depends on the knowledge which a General has of the movements and state of preparation of his enemy, but as this can seldom

be known to lookers-on, they are obliged to test his knowledge by the success of his operations.

Probably in the last two centuries there has been no instance in any campaign, with the exception, perhaps, of that of Jena, of success so rapid followed by results so important. Within seven days of crossing the frontier, the Prussians utterly routed the combined forces of their enemy in a pitched battle; within a month they dictated peace to him within sight of his capital; the result being the long desired supremacy over Northern Germany.

Military historians will have to decide how far the operations which led to this result will bear the test of criticism. The time has not yet arrived for this, as the details are not sufficiently known, but enough has come to light to enable a general view of the main features of the campaign to be taken, and to do this is the object of the present article.

It will be first desirable to form an idea of the forces with which the two countries opened the campaign.

In estimating the strength of an army, great confusion often arises from the way in which the calculations are made; in some cases artillerymen are included, and in some the number of guns only is given; sometimes officers are included, and sometimes not. In this article all combatant officers, non-commissioned officers, and men, are included; non-combatants, whether belonging to Infantry and Cavalry Regiments, or to the Commissariat, Military Train, and other non-combatant bodies are not included, nor are the officers and men of the Artillery.

The following table gives the strength of the different units of the Prussian Army, divided into combatant and non-combatant officers and non-commissioned officers and men.

	Officers.		N.C. Officers and Men.		Total.
	Combatant.	Non-Combatant.	Combatant.	Non-Combatant.	Combatant Officers, N.C. Officers, and Men.
Infantry Regiment ...	69	18	3006	178	3075
Rifle Battalion.........	22	6	1002	53	1024
*Pioneer Battalion ...	18	3	600	9	618
Cavalry Regiment ...	23	5	560	65	583
Artillery Battery......	6	1	138	13	144

There are 3 battalions in an Infantry Regiment, 4 companies in a Pioneer Battalion, 4 batteries in a Division of Artillery, and 6 guns to a battery.

The Prussian Army on a war footing consists of 8 Corps d'Armée of troops of the Line, and one of Guards. Each corps is a complete little army in itself, comprising Infantry, Cavalry, Artillery, Engineers, and the necessary proportion of Commissariat, Military Train, &c. It is divided into two divisions of Infantry, one of Cavalry, and the Artillery of Reserve.

An Infantry Division consists of 2 brigades of Infantry each comprising 2 regiments or 6 battalions, 1 battalion of Rifles or 1 battalion of Pioneers, 1 Regi-

* Pioneers correspond with Engineers of the British Army.

ment of Cavalry, and 1 division of Artillery. An Infantry Division will therefore number 12,300 Infantry, 1,024 Riflemen, 618 Pioneers, 583 Cavalry, and 24 guns.

A Cavalry Division consists of 2 brigades, each containing 2 regiments or 8 squadrons of Cavalry, and 2 Horse Artillery batteries. The total strength of a Cavalry Division will therefore be 2,332 sabres and 12 guns.

The Artillery of Reserve consists of 4 field batteries and 2 Horse Artillery batteries, and comprises therefore 36 guns.

The Military Train, and other non-combatant bodies, consist of about 3,700 men.

The strength of a Prussian Corps may therefore be summed up as follows:—

	Infantry.	Cavalry.	Pioneers.	Guns.	Train, &c.
1st Division	13324	583	...	24	...
2nd Division	12300	583	618	24	...
Cavalry Division	...	2332	...	12	...
Artillery Division......	...	...	...	36	...
Train, &c..................	...	...	...	...	3700
Total.........	25624	3498	618	96	3700

This is the nominal strength, which, of course, dwindles somewhat in time of war from absence, wounds, sickness, and other causes.

The Corps of Guards has one additional Rifle battalion and 2 additional Cavalry Regiments, its strength will therefore be 26,648 Infantry, and 4,664 Cavalry.

The Prussians had 8½ Corps d'Armée in the field, including the Guards; their nominal strength would therefore be no less than 218,828 Infantry, 30,899 Cavalry, and 816 guns. It is difficult to say what deduction ought to be made from this force in calculating the actual numbers in the field, but probably if a Corps is taken at 24,000 Infantry, 3,000 Cavalry, and 90 guns, it will not be far from the mark. This would give a total of 205,000 Infantry, 26,000 Cavalry, and 765 guns; a prodigious host, which, with the addition of artillerymen, engineers, and non-combatants, would bring the total up to little short of 300,000 men, who had to be fed, clothed, armed, and cared for, during the advance of the army into Austria.

They were divided into three armies, as follows:—

	Infantry.	Cavalry.	Guns.	Corps.
1st Army, under Prince Frederic Charles...	72,000	9,000	270	II, III, & IV
2nd Army, under Crown Prince of Prussia.	97,000	12,500	360	Guards I, V, & VI
Army of the Elbe, under Herwath Von Bittenfield.........	36,000	4,500	135	VIII & ½ VII
Total	205,000	26,000	765	

The following were the names of the Commanders:—

Corps.	Commander.	Division.	Remarks.
Guards.	Prince Auguste of Wurtemberg.	1 Von Hillier 2	With 2nd Army.
I.	Von Bonin	1 .... 2	With 2nd Army.
II.	Von Schmitt	3 Von Werder 4	With 1st Army.
III.	....	5 Tümpling 6 Mannstein	With 1st Army.
IV.	....	7 Fransecky 8 Horne	With 1st Army.
V.	Von Steinmetz	9 .... 10	With 2nd Army.
VI.	Von Mutius	11 .... 12	With 2nd Army.
VII.	....	13 Münster 14	With Army of Elbe. Not with the Army.
VIII.	....	15 Cannstein 16 Elzel	With Army of Elbe.

During the war it was found that the division was a more convenient strategical unit than the corps, and it was therefore adopted in the 3rd and 4th Corps of the 1st Army and in the Army of the Elbe; the Cavalry attached to those corps (12 Regiments) being formed into a separate body under Prince Albrecht.

The Austrian Forces opposed to Prussia consisted of 7 Corps d'Armée, to which must be added the Saxons, numbering probably about 30,000 men. The whole were commanded by "Feldzugmeister" Benedek.

The following is the strength of the different units in the Austrian Army:—

	Officers.		N.C. Officers and Men.		Total.
	Combatant.	Non-Combatant.	Combatant.	Non-Combatant.	Combatant Officers, N.C. Officers, and Men.
Infantry Regiment...	80	9	2889	341	2969
Rifle Battalion	26	4	960	125	986
Pioneer Battalion ...	22	2	768	49	790
Engineer Battalion..	22	2	712	64	734
Cavalry Regt. (light)	31	9	786	74	817
Ditto do., (heavy)	25	8	630	61	655
Artillery 4-pr. Batt.	4	...	149	11	153

There are 3 battalions in an Infantry Regiment, 4 squadrons in a heavy Cavalry Regiment, 5 in a Light one; 4 companies in a battalion of Engineers and Pioneers; 8 guns in a battery. The Horse Artillery and 8-pr. batteries have rather more men than the 4-pr. battery.

An Austrian Corps consists of 2 divisions, and is divided into brigades, the latter being the unit.

Each Corps comprises 4 Infantry Brigades, 1 Cavalry Brigade, 2 companies of Pioneers, 2 companies of Engineers, and Artillery of Reserve.

An Infantry Brigade consists of 2 Regiments (6 battalions) of Line, 1 battalion of Rifles, and one 4-pr. battery. A Cavalry Brigade consists of 2 Regiments of Cavalry and of one 4-pr. Horse Artillery battery. The Artillery of Reserve consists of 2 field and 1 rocket battery.

The following will therefore be the strength of an Austrian Corps:—

	Infantry.	Cavalry.	Engineers.	Guns.	Trains, &c.
4 Infantry Brigades...	27,696	....	....	32	....
1 Cavalry Brigade ...	....	1634	....	8	....
2 Companies Pioneers	....	....	395	....	....
2 Companies Engineers	....	....	367	....	....
Artillery of Reserve...	....	....	....	16	....
Trains, &c...............	....	....	....	....	2700
Total........	27,696	1634	762	56	2700

When 3 or 4 Corps d'Armée are employed together, a reserve of Artillery and a Cavalry Division of Reserve is added to them.

The nominal strength of the army under Benedek's command would therefore be about 223,000 Infantry, 20 or 30,000 Cavalry, and 800 guns.

As in the case of the Prussian Forces, deduction must be made from these figures for casualties; the Austrians are also said to have lost 40,000 men in the operations preliminary to the battle of Königgrätz; it is probable, therefore, that on the field of battle they did not number more than 180,000 or 190,000 bayonets and sabres, and 700 or 800 guns.

The following are the names of the Commanders of the Austrian Corps:— 1st, Clam Gallas; 2nd, Archduke Ernest; 3rd, De Thun; 4th, Festetics; 6th, Ramming; 8th, Archduke Leopold; 10th, Von Gablenz.

It thus appears from the numbers given that there were assembled on the field of Königgrätz about 415,000 combatants, exclusive of artillerymen, engineers, and non-combatants; a prodigious host, probably greater than has ever in modern times been brought together on one battle-field, except on that of Leipsic, where the forces of three empires and three kingdoms were assembled.

In order that some idea may be formed of these gigantic numbers, a list is given of the forces engaged in some of the most famous battles of the last two centuries.

Name of Battle.	Year.	Numbers.		Killed and Wounded.	
		On each side.	Total.	Number.	Proportion to total Forces.
Malplaquet.........	1709	......	188,000	18,250 Allies.	...
Hohen Friedberg.	1745	70,000 P. 70,000 A.	140,000	5,000 9,000	1/10
Prague	1757	64,000 P. 74,000 A.	138,000	16,000 8,000	1/6
Rosbach	1757	22,000 P. 55,000 A.	77,000	500 2,800	1/23
Breslau	1757	25,000 P. 60,000 A.	85,000	5,000 6,286	1/8
Lissa	1757	36,000 P. 80,000 A.	116,000*	5,000 6,574	1/10
Zornsdorf	1758	32,000 P. 50,000 R.	82,000	11,385 21,531	1/2 to 1/3
Hoch Kirch	1758	50,000 A. 30,000 P.	80,000	5,000 7,000	1/7
Marengo...........	1800	28,127 F. 30,850 A.	58,977†	7,000 6,800	1/4
Austerlitz	1805	90,000 F. 80,000 R. & A.	170,000‡	12,000 11,000	1/7
Jena.................	1806	100,000 F. 100,000 P.	200,000‖	14,000 20,000	1/6
Preussic Eylau ...	1807	85,000 F. 75,000 R.	160,000	30,000 25,000	1/3
Friedland	1807	80,000 F. 50,000 R.	130,000	10,000 17,000	1/5
Talavera	1809	52,000 E. & S. 50,000 F.	102,000	5,928 7,200	1/8
Wagram	1809	150,000 F. 130,000 A.	280,000	24,000	1/12
Salamanca	1812	...	90,000	8,000 E. 22,800 F. §	1/3
Borodino	1812	125,000 F. 125,000 R.	250,000	80,000	1/3
Leipsic	1813	150,000 F. 280,000 Allies.	430,000	50,000¶ not known.	..
Vittoria	1813	70,000 E., &c. 27,000 F.	97,000	10,000	1/10
Waterloo...........	1815	67,600 E., &c. 68,900 F.	136,500	14,000 not known.	..
Magenta	1859	48,090 F. & S. 61,640 A.	109,730	4,000 5,700	1/11
Solferino...........	1859	135,234 F. & S. 163,124 A.	298,358**	14,415 13,020	1/11
Königgrätz.........	1866	230,000 P. 185,000 A. & S.	415,000	28,000	1/15

* 2,1000 Austrian prisoners and missing. † 1,000 French and 3,000 Austrian prisoners.
‡ 19,000 Austrian prisoners. ‖ 20,000 Prussian prisoners. § Includes missing.
¶ Includes some prisoners. ** 2,770 Allies and 9,290 Austrians missing.

Having brought the forces into the field, it is now time to say something about the theatre of war in which they were to be engaged, and for this I shall borrow largely from an excellent article which appeared in Blackwood, from the pen of Colonel Hamley, the author of the "Operations of War."

The boundary line which divides Austria from Prussia and Saxony, is marked by ranges of mountains, which, starting from the neighbourhood of Zittau, run in a south-westerly direction towards Bavaria, and in a south-easterly direction towards Troppau. The first mentioned range which forms the boundary between Saxony and Bohemia, goes by the name of the Erzgeberge; the latter, which separates Silesia from Bohemia and Moravia, commences as the Riesengeberge or Giant Mountains, and, between Glatz and Troppau, takes the name of the Erlitz and Sudetic Mountains.

It will be seen from this description that in the neighbourhood of Zittau the boundary forms a great salient angle penetrating deep into Prussia and Saxony, forming as it were an advanced bastion to the Austrian Empire. The line joining Vienna and Berlin cuts the mountains at this salient angle, forming a very oblique line with the south-eastern range, from which it results that the south-eastern extremity near Troppau is much nearer Vienna than the north-western at Zittau, whilst the latter is much the nearest to Berlin. The distances from Vienna to Troppau, and from Berlin to Zittau, are very nearly the same.

This frontier has always been the scene of operations in the wars between Prussia and Austria. The names of Lowositz, Prague, Kolin, Iägersdorf, Rosbach, Breslau, Lissa, &c., in the campaigns of Frederic the Great, shew how the tide of war rolled backwards and forwards over its mountain barriers; its strategical features are therefore well known to Austrian and Prussian strategists.

The conformation of the boundary appears to offer many points of advantage to Austria.

An Austrian army in the salient angle of Bohemia paralyses a Prussian army in Southern Silesia, because it threatens its communications with Berlin, and by advancing across the Giant Mountains, would probably compel it to retire hastily and fight at a disadvantage. It is true that the Prussians from Troppau would also threaten Vienna and the Austrian communications, and the curious and intricate problem would be presented of two armies acting at the same time on their enemy's line. Colonel Hamley, in the "Operations of War," has shewn that in such a case the army whose communications were most threatened would have to give way, and in this case it is probably the Prussians to whom this would apply, because on looking further into the case it will be seen that another element must be taken into consideration. From the conformation of Silesia it happens that the sole line of communication of the Prussians is along the narrow slip between the Oder and the Austrian frontier; an advance of the Austrians on Breslau would therefore entirely cut off a Prussian army at Troppau from their supplies. On the other hand, an advance of the Prussians from Troppau on Olmütz and Brünn, although it would cut off the best lines of communication from Bohemia to Vienna, would still leave the Austrians the line by Prague to the valley of the Danube. The Austrians in fact would have the advantage, so much appreciated by all strategists, of a

"double base." They also would still be able to draw supplies from the Fortresses of Theresienstadt, Königgratz, and Josephstadt. For the Austrians, however, to be able to take advantage of these circumstances, it would be necessary that their preparations and organization should be complete; that the magazines in the fortresses should be filled, and that they should have the transport and organization necessary for shifting their line of supplies, no easy task with an army of 200,000 men. Austria notoriously went into this war unprepared, and possibly this may have made Benedek unwilling to expose his direct communication with Vienna, and caused him to cling so long with two of his corps to Moravia, as he appears to have done, instead of concentrating them earlier near Königgratz and Josephstadt.

Jomini, in his "Traité des Grandes Opérations," touches upon this point, when discussing the advantage which Frederic would have gained in 1756, if, instead of marching, as he did, into Saxony, he had advanced by Troppau straight on Vienna; he says:—"On objectera peut-être que les 30 milles Autrichiens stationnés en Bohême auraient pu compromettre le salut de l'armée; mais croit-on qu'ils seraient restés tranquillement dans ce royaume pour couper la retraite aux Prussiens, tandis que Vienne était près de succomber." It is evidently, therefore, the opinion of this great strategist, that, under certain circumstances, an Austrian army in Bohemia, if it found its communications with Vienna threatened, would not be able to venture on a counter-attack on the Prussian line of communications, but would be obliged to retire for the defence of its own, and this opinion is strengthened by the quotation from Frederic the Great given below. The problem, therefore, is by no means an easy one, and depends a great deal on the organization of the armies, the character of the Generals, and the state of military preparation of the countries.

To an Austrian army acting on the offensive against a Prussian army in its front, this salient angle of Bohemia also offers advantages, because from it Saxony on the one side and Prussia on the other are threatened, and the enemy must either divide his forces to defend both, or, by concentrating on one side, abandon the other to the Austrians.

To an Austrian army acting on the defensive, this angular frontier offers some disadvantages, because, as is shewn by Colonel Hamley, the enemy, by acting on the extremities of the lines forming the angle, can force him to quit the territory within it under pain of being cut off from his base. Frederic the Great, in his "Instructions to his Generals," illustrates this point. He says:—"If I had designed to take Königgrätz and Pardubitz in the campaign of 1745, I should have had only two days' march through the country of Glatz, for Prince Charles would infallibly have drawn off his army and abandoned Bohemia to cover Moravia, whence he drew all his subsistence. The enemy will always be jealous of any attempt upon those places which communicate with the capital or which contain his magazines."

A central position in Bohemia is however a very favourable one for an Austrian army to take up to oppose an enemy advancing through the passes of the Erzgeberge and Riesengeberge, for, with its main body concentrated at a suitable point, and corps of observation pushed on to the passes in the mountains, it is able to get the earliest information of the enemy's movements, and to fall on one or other of his corps as they debouch from the mountains.

Jomini says on this point:—"La Bohême offrait aux Autrichiens la ligne défensive la plus avantageuse. La configuration saillante au centre de tout le théâtre des opérations donnait les moyens de rassembler les masses concentriquement sur l'Elbe et de les porter même offensivement sur Dresde ou sur la Silésie. La chaîne de montagnes qui sépare ce pays de tous ceux qui l'avoisinent était en majeure partie au pouvoir des Autrichiens, et leur donnait de grands avantages offensifs et défensifs; il n'y avait qu'une opération en masse sur la Moravie qui put tourner toutes ces opérations, les rendre inutiles, et forcer l'armée Autrichienne à venir combattre sur un terrain moins favorable."

It appears therefore that the salient angle of Bohemia forms a favourable position for the assembly of an Austrian army in a war with Prussia.

It would doubtless have been to the advantage of both armies to take the initiative. Independently of the reasons given above, arising from the shape of the frontier, the attacking army has always certain advantages; the spirit of the soldiers is raised, the ravages of war are carried into the enemy's country, and, if the army is victorious, it is nearer the objective point of the campaign. There is, however, one exception to this which is given by Frederic the Great in the following paragraph, taken from his "Instructions to his Generals:"—"If I was solely attentive to my own glory, I could always make my own country the theatre of war, for there every inhabitant is a spy, so that it is impossible for the enemy to take a single step of which I am not instantly informed, and I can, without danger, harass and perplex him with large detachments as often as I think fit."

Benedek was apparently alive to the advantage of taking the offensive, and had intended to invade Silesia, but from the days of the Aulic Council until now, the Austrians were never famous for promptitude, and the Prussians were beforehand with them. This being the case, we have, therefore, only now to consider the problem of how the Prussians should best effect, and the Austrians oppose, an advance into Austria.

The ranges of mountains forming the frontier are traversed by four groups of roads fit for the passage of an army:—1st, the defile of the Elbe and the roads by Toplitz and Chemnitz, which meet at Prague; 2ndly, the roads by Rumberg, Zittau, and Friedland, which unite between Iung Buntzlau and Jicin; 3rdly, the roads by Landshut, Braunau, and Glatz, which join near Josephstadt and the first of which connects with the second group of roads at Jicin; 4thly, the roads from Glatz, Neisse, and Troppau, which meet at Olmütz. These are all first-class roads; the *Times'* Prussian correspondent states that the chaussée leading from Gorlitz to Reichenberg is broad enough to allow four carriages to pass.

At the points of junction of these roads, fortresses have been placed by Austria, namely, Theresienstadt and Prague* for the 1st and 2nd group, Josephstadt and Königgrätz for the 2nd and 3rd, and Olmütz for the 4th.

For the reasons given in discussing the frontier, it will be seen that an advance from the direction of Troppau had the disadvantage of exposing Berlin and the communication of the army to an Austrian force in Bohemia. The same may be said of an advance to the west of the Elbe, and there was this further dis-

* Prague is now worthless as a fortress.

advantage in the latter line, that the road and railroad in the Elbe valley were blocked by the fortresses of Königstein and Theresienstadt. There therefore remained the roads over the Giant Mountains, and it was by them that the Prussian Generals determined to advance.

Their enormous numbers necessitated the choice of more than one road, and hereby their difficulties were much increased. The passage of a mountain barrier on more than one line is a very hazardous operation, when, as was the case in this instance, the point of junction on the other side is in reach of the enemy, for, as the mountains do not allow of any lateral communication, each corps has to operate in ignorance of the progress of the others, and is in danger of being overwhelmed by a superior force of the enemy when it debouches on the other side. Nevertheless this operation has often been successfully performed under as unfavourable conditions as those presented to the Prussians; by Napoleon, for instance, before the battle of Jena, and by Frederic the Great before the battle of Prague.

The introduction of the electric telegraph has also simplified the problem very much. Each army as it advances is aware of the progress of its neighbours, and can regulate its movements accordingly, and there is less danger of an isolated corps advancing so far as to be seriously compromised.

The two lines chosen by the Prussian Generals for their advance were, that, which comprises the roads of Rumberg, Zittau, and Friedland, and that which comprises those of Landshut, Braunau, and Glatz. The advance by these two lines would give them the advantage that an Austrian army forming front to one line would lend its flank to the other, as actually occurred to Benedek at Königinhof, but this would hardly compensate for the danger to which each army was exposed of being beaten in detail before the other could arrive to its assistance. The *Times'* correspondent with the 1st Prussian Army, states that the troops, carriages, &c., of that army alone, when entering Bohemia, on two lines, covered 12 miles of road; it may be imagined what the extent would have been if the 2nd Army and the Army of the Elbe had been advancing on the same line; and it was probably this consideration which determined the Prussian plans.

So much for the problem as presented to the Prussian Generals. The Austrian General could not hope effectually to block each pass through the mountains. To have attempted it would have been to expose his troops to be beaten in detail; as Frederick the Great said, "Celui qui veut tout couvrir ne couvre rien." His aim should be to post corps of observation in each pass, whose duty it would be to give notice of the approach of the enemy, and to check his advance as much as possible without compromising their own safety, and to keep his army well in hand in some central position, ready to hurl it against one or other of the advancing forces before they could effect a junction.

The problem would be presented to him under the most favourable conditions if the enemy's corps advanced on him at unequal distances, so as to give him time to overwhelm one before he could be threatened by the other, and if the one farthest off was the one which would threaten least his communications when he advanced to attack the other.

Bearing these considerations in mind, let us now follow the events as they actually occurred. In doing so it must be borne in mind that the operati

are still very imperfectly known. No official accounts of the campaign have been published with the exception of a very meagre one by the Prussians, and the following descriptions are based principally upon the accounts given in the Public Press, supplemented by such information as could be obtained from officers who have been on the scene of action. I am much indebted to Major Miller, R.A., V.C., for information obtained by him from German newspapers and kindly placed at my disposal.

16th June.—On the 16th June the Prussians entered Saxony. Bittenfeld advanced from the North, whilst the 1st army covered his left wing at Lobau.

18th.—The Prussians entered Dresden, having met with no opposition.

19th.—On the 19th they advanced to Pirna, and found that the Saxons had evacuated the whole country with the exception of Königstein, which is an almost impregnable Fort, situated on a precipitous rock, commanding the road and railroad in the valley of the Elbe.

The 1st army was assembled in the neighbourhood of Görlitz under Prince Frederick Charles, and the 2nd army, under the Crown Prince, was in the neighbourhood of Glatz and Neisse. They were, therefore, favourably situated for crossing the mountains on the two lines which had been selected.

The position of the Austrian corps is known on the 11th June, through a little book which had been printed and distributed to the Superior Officers of the Prussian Army, and in which the positions of the Austrian Corps and their organization are given with great minuteness. Whether the information was obtained by the treachery of some Austrian, or by the exertions of the Prussian Intelligence Department is not known. According to this book the 1st Corps was at Prague, the 2nd at Hohenmauth and Zwittau, the 3rd at Brünn, the 4th and 6th at Olmütz, the 8th at Auspitz, and the 10th at Brunn.

22nd.—On the 22nd, the 1st Prussian Army, and the Army of the Elbe, prepared to advance. The 1st Army broke up from Görlitz, and moved to the frontier of Bohemia on the Zittau and Friedland Roads. The Army of the Elbe advanced by the Rumberg road.

23rd.—The 1st Army entered Bohemia, marching on five roads towards Reichenberg. The Army of the Elbe also advanced.

24th.—The 1st Army advanced by three roads. There were some Cavalry skirmishes at the outposts, which appear to have been the first indications the Prussians had of the presence of the enemy.

25th.—The 1st Army halted at Reichenberg.

26th.—The 1st Army again advanced. At Liebenau the advanced guard came up with four regiments of Austrian Cavalry and two batteries of Horse Artillery, which made some stand, but were soon repulsed. On the same evening they occupied Turnau. On the same day Horne's Division of the 1st Army attacked the village of Podol, where there is a bridge over the Iser, and carried it after a severe contest. This was the first serious opposition which the 1st Army experienced.

The Army of the Elbe had continued its advance, and on this day had a successful encounter with the Austrians at Hünerwasser.

27th.—The 1st Army halted to make dispositions for a further advance.

28th.—A portion of the first army advanced to Münchengrätz, where they found the Austrians in some force. They attacked and defeated them, and took

1,000 prisoners. The Army of the Elbe effected a junction with the 1st Army on this day.

It is now time to turn to the 2nd Army and see how its advance had succeeded. It had a more difficult task to perform than the 1st Army, as it was nearer the bulk of the Austrian Forces.

Benedek's Head Quarters were at Böhmisch Träbau on the 25th, and were moved a day or two after to Josephstadt. He appears to have had three corps only available to dispute the Crown Prince's advance, the 10th at Trautenau, the 6th at Neustadt, and the 8th in the neighbourhood of Josephstadt; the 1st Corps and the Saxons were opposing the 1st Army near Münchengrätz, and the remaining three corps were probably coming up from Moravia.

26th.—The 2nd Army entered Bohemia by three routes, the 1st Corps by the Trautenau road, the Guards by Braunau, the 5th Corps (followed by the 6th) by Nachod.

27th.—The advanced guard of the 5th Corps passed the frontier, and occupied Nachod on the evening of the 26th, with little opposition. On the morning of the 27th, this corps advanced from Nachod, and found the Austrian 6th Corps drawn up to oppose them near the place where the road forks to Neustadt and Skalitz. After a severe fight, the Austrians were repulsed with the loss of 2,000 prisoners and 5 guns.

In the mean time, the 1st Prussian Corps had reached Trautenau, which was occupied by the Austrian 10th Corps. They carried the place and advanced beyond, but Austrian reinforcements arriving, they were driven back again, and could not recover their ground.

The Guards on this day had advanced without opposition to Eissel and Rostelitz.

28th.—The Guards hearing of the check which the 1st Corps had received, advanced at 3 o'clock in the morning to their assistance. They took the Austrians in rear, surprised them, and drove them over the Elbe at Königinhof.

The 5th Corps again advanced and found the 6th and 8th Corps drawn up at Skalitz to oppose their progress: they attacked and defeated them.

The Crown Prince had thus successfully brought his whole army across the mountains, and had secured as trophies 15,000 prisoners and 24 guns.

29th.—The 1st Army advanced on Jicin in three columns from Münchengrätz, Podol, and Türnau. Two or three miles in front of Jicin they found the Austrians strongly posted at Lochow, on the Münchengrätz road, and near Diletz, on the Türnau road. They attacked and defeated them, taking 7,000 prisoners, and at about midnight entered Jicin.

30th.—The 1st Prussian Army was concentrated round Jicin, where it opened communication with the 2nd Army, who were between Miletin and Grädlitz with their centre at Königinhof.

1st July.—Benedek had taken up his position along the railroad fronting the Elbe, between Königinhof and Josephstadt, but the capture of Jicin having exposed his left flank, he quitted his position on the morning of the 1st of July, and prepared to take up a new one behind the Bistritz.

The strategical operation of concentrating their armies on the other side of the frontier may now be said to have been successfully accomplished by the

Königgrätz, yet they were now sufficiently near to afford each other mutual support in case of attack. Before entering upon the description of the battle, it will be well to review the operations on both sides which led to it.

The operation which the Prussians undertook, was, as before stated, a dangerous one. They entered the mountains at points 60 or 70 miles apart, separated by lofty mountain-ranges allowing of no lateral communication, and had to concentrate their armies on some point in the plain which was held by the Austrians.

The control of the operations is generally attributed to General Von Moltke. At Berlin the telegraph wires flashed to him from day to day the positions of the armies, and he was able to regulate their movements so that they should advance by proportionate steps. Had one of the armies met with so serious a check as to have compelled it to retreat, he could probably have prevented the others from being compromised by too forward an advance, and the danger of any serious disaster was much diminished by this. But the most important questions in considering the danger and merit of the movements are, how far was the Austrian General prepared to meet it, and what knowledge had the Prussian Generals of their enemy's positions. It has been shewn that the best situation for the Austrian General would be to have the enemy advancing on him at unequal distances, to keep the one furthest off in check, and to throw himself on the other and crush it before it could receive assistance; and an additional element of success would be that he should be able to advance on the army nearest him without throwing open his communications to the other.

Let us now consider the positions* of the different corps on the 28th, which appears to have been the most critical period in the Prussian movements, and see how far the conditions of the problem were favourable, or the reverse, to the Austrian General. On that day the 1st Prussian Army and the Army of the Elbe (about 120,000) were between Türnau and Münchengrätz. The 2nd Prussian Army was debouching from the passes at Trautenau and Skalitz. The distance between the nearest flanks of the two armies was 40 or 50 miles, and the main road passed through Jicin, which was in the hands of the Austrians. The 2nd Army could not therefore have received any assistance from the 1st Army under two or three days. The distance of the 1st Army from Josephstadt, where Benedek had his head-quarters on that day, was about 50 miles; the distance from Josephstadt to Skalitz, on which two corps of the 2nd Prussian Army were marching, was about 7 miles; and the distance to Trautenau, where the other two corps were engaged, was about 20 miles. The conditions up to this time appear to have been very favourable to Benedek. The Prussian armies were so far apart that they could not expect any mutual support. The 2nd Army was much nearer to him than the 1st, and he could attack the former with much less danger to his communications with Vienna than if he advanced to meet the 1st Army, leaving the 2nd Army on his right flank. His object therefore should apparently have been to check the advance of the 1st Army with a small force, whilst he attacked and crushed the 2nd Army with his whole strength. Let us see how far he carried this out.

* The positions are shewn on Map No. 1 by rectangles, blue for Prussians and red for Austrians, each rectangle representing a corps.

The Austrian 1st Corps and the Saxons, numbering about 55,000 men, commanded by Count Clam-Gallas, were checking the advance of the 1st Army between Münchengrätz and Jicin. This was a very proper arrangement, but it is doubtful whether it was well carried out. The duty of a corps in such a position is to be continually harassing the enemy, obliging him constantly to deploy, and thereby delaying his advance, but not allowing itself to be drawn into a pitched battle. This requires a very skilful commander, and Clam-Gallas, perhaps, was not equal to the occasion. Instead of occupying successive positions, and taking advantage of every accident of ground, he accepted battle before Jicin, and allowed his army to be so irretrievably compromised, that it was routed with the loss of 7000 prisoners. One of Benedek's Corps was at Trautenau, where it was exposed to the attack of two Prussian Corps; and two corps, one of which had been severely handled the previous day, were at Skalitz, opposed to the remainder of the 1st Army. He had, therefore, three corps opposed to the four corps of the Crown Prince. *Where were Benedek's three other corps, which should number* 80,000 or 90,000 *men, and which must have turned the scale against the Crown Prince ?*

The three missing corps were the 2nd, 3rd, and 4th, and on the authority of the "little book" before-mentioned, they were stationed on the 11th June at Hohenmauth, Zittau, Brünn, and Olmütz. The presumption, therefore, is that they were still on the road from Moravia, and that Benedek had not been able to complete the concentration of his army in sufficient time; the consequence of which was, that the Prussians, in debouching from the mountains, found themselves equal to or superior to their enemy at every point. It is impossible to say, with our present information, whether this failure on the part of the Austrians was owing to want of preparation, or to bad strategic operations; if the latter, it illustrates remarkably an observation of Frederic the Great. "A "defensive war is apt to betray us into too frequent detachments. Those "Generals who have had but little experience attempt to secure all, whilst "those who are better acquainted with their profession having only the capital "object in view, guard against a decisive blow, and acquiesce in small "misfortunes to avoid greater. He that grasps at everything seldom succeeds "in all." It must be remembered that the Crown Prince, before his entry into Bohemia, had been making demonstrations in the direction of Troppau, and this may have made Benedek uneasy for his communications with the capital.

The Austrian losses during these operations are estimated at 40,000 men and 24 guns.

1st July.—The position which Benedek determined to take up upon moving from Königinhof, was between the Bistritz and the Elbe, on a range of hills running parallel to the former stream, which, although only an insignificant one, is passable by troops only at the bridges. This range has its culminating point at Chlum, from whence it runs in a south-westerly direction, gradually losing height, and almost sinking into the plain between Tresovitz and Streselitz. In a north-easterly direction it runs towards Horenowes and then sweeps rather to the right towards the Trotinka, near Racitz. The top of the ridge is about a mile and a half from the Bistritz, towards which the slope is tolerably steep and broken, whilst towards the Elbe the ground falls with a very gentle inclination, in no part affording any obstacle to manœuvring Cavalry and Artillery. Still

more to the south-west the ground again rises towards Lubno, reaching its culminating point in the high ground above Nechanitz, on which the Castle of Hradek is situated. A little to the rear is some high ground on which are situated Problus and Upper Prim. The culminating point of the whole position is the hill of Chlum, on which the church is situated, and from which an extensive view can be obtained on every side.

On the afternoon of Sunday the 1st of July, the inhabitants who were assembled in the church of Chlum for Divine service, were surprised to find among the congregation an Austrian General and his Staff. They were part of the great army who all that day and up to noon of the following day were pouring in to take up their position on the intended field of battle. It is a disputed point how far the Austrians had intrenched their position before the battle. From the statements of those who have been over the battle-field, it seems that this had been very imperfectly done. Trees had been cut down in places to form obstacles, slight intrenchments had been made, but they appear to have been very unfinished, and there seems to have been no method or connection between them. At Chlum there were some very insignificant intrenchments across the Mastowed road, and one or two batteries had been thrown up. The wood at Sadowa had apparently been well prepared for defence by cutting down and interlacing the trees.

The deficient nature of the intrenchments may probably be accounted for, partly by the fact that the troops were harassed by the previous marching, partly by the supposition that Benedek did not expect to be attacked on the following day, which expectation was very near being realized.

A Council had been held on the afternoon of the 2nd at the head-quarters of the King of Prussia, who was with the 1st Army, at which General Blumenthal, the Chief of the Staff of the 2nd Army, had assisted. At this it had been determined not to engage on the next day, and it was decided that the 2nd Army should make an extensive reconnoissance across the Elbe beyond Josephstadt. General Blumenthâl returned to the Crown Prince with this information, but in the mean time a Prussian Cavalry reconnoitring party had had an encounter with Austrian Cavalry in the wood near Sadowa. They were nearly cut off, but managed to escape with the important intelligence that the Austrian Army were assembled in position with the Elbe in their rear. On learning this, it was at once determined to attack on the following morning. Messages were dispatched to that effect to the different divisions of the 1st Army and of the Army of the Elbe, and a *single Staff Officer* was sent to the Crown Prince's head-quarters to announce this determination and to request his co-operation. The officer had to ride 20 miles, and reached the quarters of the Chief of the Staff of the 2nd Army at 1 o'clock in the morning; he returned with the answer that the 2nd Army would be on the field of battle as soon as possible.

The decision to attack at once was certainly bold and energetic, and probably judicious, as it prevented the Austrian Army from having time to recruit and to intrench themselves. That the message on which the co-operation of the 2nd Army depended should have been entrusted to one officer alone, is one of those inexplicable errors which recalls the saying of Napoleon: "He who has never made mistakes has never made war."

The positions of the Prussian Armies on the 2nd were as follows:—The 1st Army was in the neighbourhood of Kamenitz, where Prince Frederick Charles had his Head Quarters. The Army of the Elbe was between Hoch Wessely and Smidar on their right. The Head Quarters of the 2nd Army were at Königinhof and the army extended from near Miletin to Gradlitz.

The General plan of the Prussian attack appears to have been that the 1st Army was to attack the Austrians in front; the Army of the Elbe was to advance on their left flank by Nechanitz, and the 2nd Army to attack their right flank between Horenowes and the Trotinka.

BATTLE OF KÖNIGGRÄTZ.

3rd July.—Austrian Position.—The Austrians occupied the line of hills before-mentioned, between the Bistritz and the Elbe. Their position extended about 8 miles. Their left rested on Problus and Upper Prim, their centre was in front of Lipa and Chlum, and their right rested on Horenowes. They had a Cavalry Corps near Trotinka. There was a battery on the hill to the south-east of Horenowes, on which there is a big tree, and the ground between Horenowes and the Trotinka was probably, to a certain extent, occupied.

The corps were arranged as follows:—The left wing consisted of the Saxons and 10th Corps, with the 8th Corps in reserve; the centre consisted of the 3rd and 4th Corps, who were round Lipa and Chlum. The 2nd Corps stood on the right towards Horenowes. The 1st and 6th Corps were in reserve near Rosberitz. The Cavalry was behind on the Königgrätz-Sadowa road. The general outline of the position is shewn on Map No. 2, in skeleton red, but no attempt has been made to define the exact places of corps and regiments, who were undoubtedly posted so as to take advantage of the irregularities of the ground. The woods and villages along the Bistritz were occupied, especially the woods on the right and left of the Königgrätz-Sadowa road, which were obstinately contested throughout the day. The slopes facing the Bistritz were lined with batteries, and the Saxons had a battery on the hill near Hradek Castle. Nechanitz seems to have been very slightly occupied. Benedek took up his position for the first part of the battle on a little hill in rear of Tresowitz, and moved, probably about 10 or 11 o'clock, to the hill of Chlum.

Prussian Position.—About 6 a.m., the 1st Prussian Army was assembled behind the hills on which the village of Dub is situated. The 2nd Corps, consisting of the 3rd and 4th Divisions, was on the right of the Königgrätz road, the 8th Division of the 4th Corps was on the left; the 7th Division of the same Corps was on the other side of the Bistritz at Cerekwitz. Prince Frederick Charles took up his position on the hill above Dub. The 3rd Corps, consisting of the 5th and 6th Divisions, with the Cavalry, were in reserve on the Königgrätz road.

The Army of the Elbe was advancing from Neubidsow on Nechanitz.

The 2nd Prussian Army was near Miletin, Königinhof, and Gradlitz; the 1st Corps was at Ober Prausnitz, the Guards at Königinhof, the 5th Corps between that place and Gradlitz, and the 6th Corps at Gradlitz. Their distance from the right of the Austrian position was from 12 to 15 miles.

The strength of the whole Prussian Army was about 230,000 bayonets and

sabres, but of these the 5th Corps and one brigade of the 6th Corps at least never came into action. This would reduce the numbers engaged to about 200,000. The strength of the 1st Army, and of the Army of the Elbe, which, from 7 to 11 or 12, were opposed alone to the whole Austrian Army, was about 120,000. The strength of the Austrian Army was about 185,000.

BETWEEN 7 AND 8 A.M.—The guns of the 1st Prussian Army advanced, and a furious cannonade commenced, extending from Mokrowous to Benatek. The Austrians replied from their numerous batteries on the slopes facing the Bistritz.

ABOUT 9 O'CLOCK.—The village of Benatek took fire. The 7th Division made a dash to secure it, and succeeded in driving out the Austrians.

Between Sadowa and Mokrowous, the severity of the Prussian fire had compelled the Austrians to withdraw their batteries higher up the slopes. Prince Frederick Charles then ordered an attack on the villages of Sadowa, Dohalitz, and Mokrowous by the 8th, 3rd, and 4th Divisions respectively. These villages do not seem to have been put into a proper state of defence by loopholing houses, erecting barricades, &c. They were, however, hotly contested for some time, but,

BY 11 O'CLOCK the Prussians had gained possession of them, and their batteries were then brought over the Bistritz, the Austrians forming a new line higher up the slope.

The 7th Division had in the mean time carried the lower part of the wood near Benatek, after a tremendous struggle in which one Prussian Regiment is said to have lost 2,500 out of 3,000 men. They appear to have maintained themselves in the wood up to the end of the day, but they were to a certain extent isolated and in considerable danger.

The Prussians now attacked the wood to the south of the Sadowa road, which was hotly contested, and in which a hand to hand fight was going on through the whole day. They did not at first make much impression, but at length succeeded in driving the Austrians back to the centre. Here they could make no further progress, and although at 1 *o'clock* Prince Frederick Charles sent his reserves to their assistance, they rather lost than gained ground. It has been estimated that there were 90,000 men fighting within this wood.

The 1st Army had now brought all its available troops into action, but without making any impression on the Austrian centre. Benedek was preparing to bring up his Cavalry, and the Prussian Generals were beginning to fear that they would not be able to hold their ground, when the approach of the Crown Prince changed the aspect of affairs. It is now time to turn to the operations of his army and of the Army of the Elbe.

The Army of the Elbe had reached the Bistritz at Nechanitz about 8 a.m., but they do not seem to have crossed in force until about 10, when they drove the Saxons from their battery near Hradek Castle. The Munster Division then advanced by Hradek to turn the Austrian left at Prim. The Cannstein Division advanced by Lubno against Problus. The latter met with little opposition until it had got beyond Lubno, when it came under heavy fire. Prim and Problus do not seem to have been taken until past 3 o'clock, when the Austrians were beginning to feel the effects of the Crown Prince's advance. One brigade of the remaining division had advanced on Charbusitz. The other brigade of this division was in reserve.

The Crown Prince had received information of the intended attack at about 2 o'clock a.m., of the 3rd, and by

ABOUT 7 O'CLOCK A.M., his army was ready to advance. The distance which they had to traverse to reach the right wing of the Austrians was from 12 to 15 miles.

The 1st Division of the Guards advanced by way of Daubrawitz* upon Wilantitz; the Artillery of Reserve followed, and subsequently the 2nd Division en échelon on the left wing. The roads were very heavy and the ground hilly, which materially impeded their progress. Captain Webber, R.E., who visited the ground, states that the roads are execrable, for the most part little better than tracks, and that from the marks of the wheels it was evident that the guns had in many places been taken across country. At Choteborek, which they reached about 11.15, they first came in sight of the enemy. From that place they found their march impeded by impassable wet meadows which could only be crossed by the roads at Jericek and Lhota.

The 1st Corps, followed by the Cavalry Division, had in the mean time advanced from Ober-Prausnitz, past Miletin, towards Gross-Bürglitz; the 6th Corps, having detached a brigade to observe the fortress of Josephstadt, marched from Gradlitz towards Nesnasow, and the 5th Corps advanced in the rear towards Choteborek.

The Crown Prince advanced in front of his army; he was ignorant of the country, of the Austrian position, and of the progress of the 1st Army; but seeing by the firing that the right of the battle appeared to be about Horenowes, he directed the march of his columns on the big tree, to the south-east of that place. (See map.)

ABOUT 12 O'CLOCK.—The artillery of the 1st Division of Guards, and of the 6th Corps, opened fire against the Austrian position, between Horenowes and the Trotinka. The other division of the Guards and the remaining corps of the 2nd Army had not arrived.

ABOUT 1.30.—The position of Horenowes was carried by the Prussians, and the Austrians retired to a second position between Mastowed and Sendrasitz. The whole of the Austrian Brigade in Horenowes is said to have been captured.

ABOUT 2 O'CLOCK.—This position was also carried, and the Austrians retired to a third position. The Austrian Cavalry made an attack upon the Prussian batteries at Mastowed but were driven off.

FROM 2½ TO 3 O'CLOCK.—It is not clear what number of Austrian troops the 2nd Army had to encounter in their advance, or what part of the army they were taken from, but it appears that about this time Chlum was left altogether denuded of troops. It is stated by some that the Austrian Corps which was pushing back the 1st Army had advanced too much and left a gap in the line; the corps which were opposed to the Crown Prince necessarily formed an angle with those which were resisting the 1st Army, and it is a well-known defect of such a position, which has been illustrated by many battles, that the advance of one portion of the army is apt to leave a gap at the angle. By some it is said that this gap was caused by the defection of some Italian regiments who were in this part of the line. It is also possible that the troops who were defending

* This may be intended for Dubenetz, which seems the more probable line of advance to Wilantitz.

the Horenowes ridge, fell back too much to the right, towards Sendrasitz. Whatever may have been the cause, the 1st Division of the Guards entered Chlum with hardly any opposition.

The 2nd Division of the Guards had been delayed in crossing the wet meadows near Lhota; it then advanced toward the big tree, wheeled to the right and took the direction of Lipa. The accounts of the position of the 6th Corps are rather confused; part of it, probably, co-operated in the attack of the Guards, and the remainder was advancing on Sendrasitz and Trotinka.

As this appears to have been the most critical period of the day, the positions of the armies are shewn, in dark blue for the Prussians, and dark red for the Austrians.

Benedek, on hearing that some Prussians were behind him, galloped with his staff to Chlum. They were received by a heavy fire. He then endeavoured to re-take the place with some of the reserves, but the Prussians, by this time, had brought up more guns and troops, and succeeded in holding it.

The 1st Division of the Guards then attempted to take Rosberitz, but here they were met by superior forces, and as they were unsupported by the 1st and 6th Corps, who had not yet come up, they were obliged to retire to Chlum. The Artillery of Reserve also had exhausted their ammunition.

About Four o'Clock.—The 1st Corps arrived. With their assistance the 1st Division then advanced on Rosberitz, and the 2nd on Langenhof. A little before this the King of Prussia had arrived on the ground at the head of the Cavalry of Reserve, having crossed Bistritz near Dohalicka.

The 2nd Army having thus established itself on the Austrian right flank and rear, there was nothing left for Benedek but to effect the best retreat he could. The Austrian guns took up a last position on the hills above Rosnitz.

The Battle of Königgratz and preliminary operations illustrate very forcibly the advantages and disadvantages which Colonel Hamley, in his "Operations of War," shews to be the result of "combined armies operating from divergent bases," and of which he gives the Waterloo campaign as a typical example. The disadvantages being that they are liable to be beaten in detail; the advantages, that they act on their enemy's flank, and, if they can combine, the blow is likely to be more effective than if they had a common base, because the enemy is obliged to form on two fronts to meet the attack, and if driven in on one, the rear of the other and his communications are exposed, of which danger the advance of Blucher on Planchenoit, at the Battle of Waterloo, is a striking illustration.

The Prussians were acting on divergent lines, the 1st Army by Königgrätz-Zittau, the 2nd by Königgratz-Braunau. The disadvantage of this was shewn on the 28th June and on the 3rd July. On the former day they were only saved from being attacked in detail with superior forces, by the fact that Benedek had not completed the concentration of his army; on the latter their 1st Army was opposed alone for four hours to the whole Austrian Army, and it is difficult to see why Benedek did not take advantage of this to strike a blow before the 2nd Army came on the field. Probably the explanation is that he was not well informed of the position of the Prussian Armies, and that he did not expect that the Crown Prince would have reached the field of battle so soon as he did.

The advantages of the divergent bases of the Prussian Armies were exemplified on the 30th June, and at the Battle of Königgrätz. On the former day Benedek was obliged to abandon his position at Königinhof, on account of his left wing being exposed to the 1st Army at Jicin; and on the field of Königgrätz the divergent action of the 2nd Army was the cause of his right wing being doubled up, and of his line of retreat being threatened by their attack.

It is particularly interesting to see the principles of war which have been worked out by the military historian in his closet thus practically confirmed on the field of battle.

The retreat seems to have been very well covered by the Austrians, so much so that the Prussians did not venture on any pursuit. That the Austrian Army were so completely demoralized and broken up must be attributed to their fighting with a river at their back. Both their wings being driven in, the retreating army was forced in a wedge on to the river, men, guns, and horses crowded on to the few bridges in inextricable confusion, and the army emerged on the other side a helpless and terror-stricken mob.

The losses in this battle were very small, considering the number of men engaged and the duration of the fighting. On referring to the list given at page 179, it will be seen that the proportion of the number of killed and wounded to the total forces engaged is smaller than in almost any of the battles named, being only $\frac{1}{15}$th, whilst in several the proportion was from $\frac{1}{3}$rd to $\frac{1}{7}$th. (It is worthy of a passing remark, that, excluding the Battle of Leipsic which lasted three days, the three most sanguinary battles of the last two centuries, Zornsdorf, Preussic-Eylau, and Borodino, were fought against Russians). The number of prisoners taken was large, (about 18,000 with 174 cannon) but this has been equalled at Lissa, Austerlitz, Iena, and Leipsic. It is stated by the *Times'* military correspondent with the Prussian Army, that the number of cartridges fired barely exceeded one per rifle, that hardly any soldier fired so many as 90, and few more than 60*. In the Artillery of the Guard the 13 batteries engaged fired 1,787 rounds, being an average of 23 per gun; one battery fired 81 rounds per gun.

The following interesting description of the ground, and criticism of the battle, is by Capt. Webber, R.E., who visited the scene of action after the battle, and to whom this article is also indebted for the panoramic views of the field and a sketch taken by himself on the spot.

"In no part of the position is the ground difficult on account of its inclination, the steepest part being under 10°, and the average about 3°. A circumstance which, if favourable to the attacking party in one way, nevertheless places the artillery of the defender in an advantageous position, though it obliges him to distribute the guns over a greater space. Some idea of this may be formed when it is found that if the Austrians had 500 pieces in action on the front, extending from Hradek to Horenowes, there would have been a gun to every 20 yds.

The most commanding points of the position are Hradek, Problus, and Chlum.

The ground between the imperial road, Lubno, and Prim, may be considered very open, the space is studded chequerwise with villages (of which there are seven), with one commanding knoll behind Tresowitz.

Considering the position as only attacked on one side, the flanks were undoubtedly strong. Nechanitz on the left supported by the wood and castle of Hradek is capable of protracted defence, being covered by marshy ground and mill streams, and having strong stone houses. On the right the tenure of the wood north of Chlum, and the village of Horenowes, completely prevented the flank being driven in.

The Austrian left-centre was then the most vulnerable point, and the capture of Problus was a more profitable object than that of Chlum, but each village in the open ground would have to be won in succession.

Apparently this would not have been difficult, as the Austrians evacuated such points as the sugar factory and the church of Dohalicka, the moment the Prussian advance made their tenure dangerous to the defenders.

If they had been held as Hougoumont was at Waterloo, the Prussian artillery might have hit them from a distance, the infantry tried to storm them, and the cavalry pass between them, in vain.

These seven villages, properly placed in a state of defence, with Prim and Problus in rear, and cavalry ready to charge on the easy ground between them, might have been held by 12,000 good soldiers through half the day.

The Saxon defence of Nechanitz, and their battery on the right of the wood of Hradek were most paltry, and they need never have left the wood. Their battery for 9 guns was badly placed. It should have been subdivided and placed lower down the hill, and Lubno held.

The failure of the Prussians through the morning to take the Sadowa and Obora woods, shews the possibility of the Austrians making a good stand among trees against the destructive arm of their opponents.

Looking at the question as it really stood, in a strategical point of view, Ramming, Gablenz, and Prince Leopold, should never have fought the Crown Prince after Nachod, but have *held* the Prussians on that side as long as possible by occupying the strong position west-north-west of Josephstadt, which having the Elbe in its front and a railway throughout its extent, might have been done with few men.

At one time this was the intention, as 8 batteries had been erected on the right over Kukus.

Thus holding the 2nd Army the 1st might have been attacked.

But the fight by Jicin, on the 29th June, turned this position, and the Austrians having destroyed all the bridges on the Elbe, and blown up a railway viaduct, evacuated it on the night of the 30th, and the mass of the Austrian Army, far from being in a position to attack Prince Frederick Charles, was east of the Elbe.

It being then as much as Benedek could do to bring his army in position before Königgrätz, the question is, was he ignorant or not, that from the 1st June the Crown Prince was within 10 miles of his right.

If he was ignorant of the fact, his sources of information must have been bad. If not, his mistake lay in supposing he could beat the 1st Army before the 2nd came up.

This was possible, had he detached a corps to his right to the strong ground between Dubenetz and Luzan, to delay the latter for a few hours. Even

without that, if the villages along the Bistritz had been held, and Nechanitz strongly garrisoned, 100,000 men, including the reserve, were available to turn on the right front and rear, and repel the attack if the movement had been made early enough, but Benedek was intent on his west, whereas if he had had the cupola of Chlum church tower blown off, he could have thence seen *both* fronts. But even when too late for this movement, there was still a chance of retrieving the day, if Nechanitz had not been lost, by pivoting on that point and throwing the whole right back even as far as Techlowitz.

This would have been doubtless a losing game, but the army would not have been lost, as the retreat to the south and south-west would have been open, and the Prussians could not have gone south without fighting again.

The turning of the Austrian right being inevitable, the loss of Chlum was a lesser evil than that of Nechanitz and Hradek.

On the tenure of the woods and villages depended the success of the Austrians in the battle on their west front. The former appear to have been retained long after the latter had been evacuated.

The villages were not placed in a proper state of defence, the entrances not having been even closed. Abattis were insufficiently used, and the strong stone buildings, which were quite capable of resisting field artillery, not loopholed.

As some of the Austrian Army was at Sadowa two days before the battle, this would have been practicable.

The defences of Chlum (see Pl. III), were incomplete, the north and north-west only being touched. The Crown Prince attacked it on the north-east side.

Breastworks without abattis may be useful to cover a handful of determined men, but advancing troops will run over them. If possible, the one kind of defence should never be used without the other."

C. E. WEBBER,
Captain, Royal Engineers.

The Austrian Army retreated in the first instance to Olmütz, with the expectation, probably, that the Prussians would not dare to march on Vienna, leaving a fortress and army on their flank; in this, however, they were deceived.

5th.—The Prussians made no advance on the 4th, but on the 5th they crossed the Elbe in three places, and advanced in three columns on Vienna. Their lines of march, and the dates of their reaching the different places, are shewn on the map.

15th.—On the 15th, Benedek broke up from Olmutz, and retired, by forced marches, across the mountains to Presburg. There was a skirmish between a portion of his army and that of the Crown Prince on that day near Tobitschau.

22nd.—On the 22nd, a part of the 1st Army attacked the Austrians near Blumenau. A division had crossed the mountains and got into the Austrian rear, when the action was stopped by the announcement that an armistice had been concluded.

The line of demarcation between the two armies adopted during the armistice is shewn on map No. 1.

Peace was concluded on the 23rd August, between Austria and Prussia.

It is curious to speculate on what would have been the course of the war had peace not been concluded.

The Austrians had erected an enormous bridge-head at Floridsdorf, covering the railway junction there, and the bridge over the Danube. This appears to have consisted of a triple line of earthworks on an indented trace, the outer one of which had a length of some miles, and the whole bristled with guns.

The Prussians appear to have been anxious to secure the possession of Presburg, for the last action of the war was caused by their sending a force to carry the passes of the mountains leading to that place. The Austrians, on the other hand, did not intend to hold it, as before the time. when, if the truce was not renewed, hostilities would recommence, they evacuated Presburg and retired across the Danube.

The Prussians were at a great distance from their base; their troops were beginning to suffer from privations and want of provisions, and sickness was breaking out among them. The difficulty of bringing up supplies would have been materially increased by the stoppage of their only line of rails, owing to one of the bridges on it having been destroyed by the garrison of Theresienstadt. The Austrians were still in great force, they had been reinforced by troops flushed with the victory of Custozza, and they were fighting in presence of the Emperor and for the Capital of the country. On the other hand, the Prussians had the needle gun and the prestige of success, better Generals, and more homogeneous soldiers. The problem presented by this combination of moral and material causes is one the only solution of which was prevented by the conclusion of peace.

The causes of the triumphant success of the Prussian arms may probably be reduced to three: better generalship and organization; better state of preparation; and the needle gun. But if we attempt to disentangle these causes, and to ascertain the exact value to be given to each, it will be found a very difficult task.

The success of their strategical operations was probably due to all three causes. It was to the promptitude of their movements, the result of carefully laid plans, well prepared for, and energetically carried out, that they owed the fact that in the invasion of Bohemia they found themselves debouching from the mountains on the 28th June, equal or superior to the enemy at all points. A day or two's delay, or any failure in their organization or supplies, would have probably afforded Benedek time to bring the three missing corps into line, which, as before stated, would have given him such a preponderance over the Crown Prince that he would hardly have failed to drive him back to the mountains. The needle gun must be undoubtedly credited with some of the results of these preliminary operations. In the actions at Nachod, Skalitz, Münchengrätz, &c., the Austrians first felt its effects, and partly from fear of it, partly from want of confidence in their Generals, they appear to have lost morale. The *Times*' special correspondent with the Austrian Army writes on the 30th July: "It is as well to state the truth at once. The Austrian Army was beaten before the 3rd of July. It had lost morale. Its Generals were disobedient; they violated the orders of their chief. They got soundly beaten; their men lost confidence in them and in themselves, and became filled with despondency. It may be remembered that in my account of the night march on Dubenec I remarked

how silent the men were. I did not then consider it significant, because I was not acquainted with the manners of the Austrian Army; but I now know the silence was a sign that the men were out of heart, and that it was quite unusual. These men had been either engaged with the Prussians, or had heard of the results of the combats at Skalitz and elsewhere. They were down-hearted; they were cowed; and although most of them fought bravely on the 3rd of July, and many regiments displayed a courage and endurance which their enemy thoroughly appreciated, and which could not have been surpassed by any troops in the world, on the whole, it must be said the army fought without confidence, and that it lacked spirit and the sentiment of hope and belief in success which gives a body of men *élan* and pervades them like a soul. Benedek perceived before the battle was fought that his army was not what it ought to be. It stands recorded as a solid and singular fact that when he fought that battle he believed he would be beaten. (Two days before the Battle of Königgratz the Commander-in-Chief sent a message to the Emperor which must have shaken his very throne: 'Sire, you must make peace.')"

The *Times*' military correspondent with the Austrian Army writing during Benedek's retreat from Olmütz, says: "It is painful to have to relate the demoralization of brave troops, but I am compelled to say that the infantry had by this time lost all heart. They had been taught that their rush was to be irresistible, and they had filled up hecatombs of slain in front of the first Prussian positions in their gallant attempts to verify their belief; but they had failed, signally failed, to drive back those lines topped with spikes and fringed with immoveable steel and perpetual fire. The odds were always three or four to one against them, even if the number of men were equal; what now remained but to creep home to Vienna and tell their Emperor that his children had been faithful unto death, though so cruelly beaten, and to warn him that they could not win under the conditions placed before them. Every messenger from Vienna was charged to say on his return: 'Make peace, or the army will be annihilated.' Every spirit was oppressed for the gravity of the situation. Every heart failed for fear. And yet, not all: Prince Rupert's cavaliers were never more confident nor more reckless than were Edelsheim's Hussars and Lancers. How they dashed at everything in the shape of cavalry that appeared; how they harassed the enemy and protected their army's retreat; how they tried to tempt the Prussian horsemen to engage with 'Blanken Waffen;' and how completely (whatever the Prussian officials may say) they established the superiority of the Austrian Horse, will some day be described by a more eloquent pen than mine."

At the Battle of Königgratz the needle gun does not appear to have had directly any great effect on the battle, but the loss of morale which, if the *Times*' correspondent is correct, it had caused, was probably one element of failure. Here again, however, we trace the energy of the Prussians and the want of it of the Austrians. The Prussian Generals only heard on the night of the 3rd of the position of the Austrian Army, but they determined to attack at day-break, and in this no doubt they were right, for the Austrians were weary and dispirited with marching and countermarching, and a day's rest would have been of great value to them to recruit and intrench the ground. The hastiness of the decision was undoubtedly the cause that the 1st Prussian Army was engaged single-handed for four hours, but as the Austrians took no advantage of this, the Prussians did not suffer from it.

We get glimpses throughout the whole of the war of Austrian operations which

do not impress us with a favourable idea of the organization of the army or of the skill of their Generals. It is one of the disadvantages of operating with such prodigious armies, that you require not only a General capable of manœuvring 200,000 men, which Napoleon said was a gift vouchsafed to very few, but you also require able leaders for the several Corps d'Armées, each one of which is an army of no mean size. The force under Clam Gallas at Jicin, or under Gablenz at Trautenau, were greater than that with which Frederic won the Battle of Rosbach, or Napoleon that of Marengo. The Commanders of the Austrian Corps do not seem to have been equal to the occasion, and of this many instances may be given. When the Crown Prince entered Bohemia his 1st Corps and Guards were advancing on two parallel roads across the mountains; the 1st Corps was driven back and effectually held in check by the Austrian Corps at Trautenau; the Guards continued to advance on the parallel road, from which there was a communication on to the right and rear of the Austrians at Trautenau. It might have been thought that the Austrian Commander would have suspected that the Crown Prince, who was crossing the mountains with his whole army, would not leave this road unemployed, and that he would consequently have watched it jealously, but this does not appear to have been the case, and accordingly the next morning, when the 1st Division of Guards marched on Rugnitz to take the Austrians in rear, the latter, according to the *Times*' correspondent, "were surprised in their bivouack."

The Austrian Commander, whose duty it was to check the Prussian advance from Neisse, does not seem to have made the most of the ground. Captain Webber, R.E., visited the pass of Nachod, and from a report which he made the following is gathered:—Nachod is about four miles from the frontier, and about eight from Neustadt, where an Austrian Corps, under Ramming, was posted to watch the passes. There is a strong schloss at Nachod situated on an eminence, on which 40 guns might have been placed which would have completely swept the only road of approach. About a mile behind there is a very good position for an Austrian Corps to have taken up to oppose the Prussian advance, where they would have had the advantage of ground, and which is within two or three hours' march of Neustadt, where the Austrians were posted. About a mile further to the rear the ground begins to slope to the Austrian side, and there the Prussians would therefore have the advantage. There is a small stream at the frontier crossed by a stone bridge. If the Austrians, therefore, blew up this bridge, put a small corps of observation there, and placed a battery at the Schloss of Nachod, supported by some troops, they ought apparently to have been able to reach the position in rear of that place before the Prussians. The course of events was this: they blew up one arch of the bridge, occupied Nachod with a squadron of cavalry, a company of infantry, and two guns only. The Prussians crossed the stream in the afternoon, and their advanced guard occupied Nachod about 5 p.m. They then repaired the bridge. The Prussian 5th Corps, and one brigade of the 6th, advanced on the morning of the 27th, and met with little opposition until they were debouching from the pass in the position where they had the advantage of ground. Here they were attacked by the Austrian Corps unsuccessfully. The Austrians seem to have been again a little too late.

At Königgrätz there is the inexplicable fact that a whole army was advancing against the Austrian right flank without anybody having apparently informed

the Commander-in-Chief of the gravity of the circumstances, or the equally inexplicable fact that if he was informed of the danger he took no effectual steps to meet it.

In the last action of the war, as described by the *Times'* Prussian military correspondent, there is a hardly credible instance of the want of organization of the Austrians. Fransecky advanced on the 22nd July to attack the Austrian force, which was in position near Blumenau, defending the road to Presburg. He sent 5,000 men, under General Bose, by a mountain path to the left to get into the rear of the enemy whilst he himself attacked them in front. Bose executed this manœuvre successfully; he encountered on the Gamsenberg the Austrian "Schwartz and Gelb" Brigade, drove them back, and succeeded in planting himself across the Presburg road in rear of the Austrians. *He communicated the information to Fransecky*, who prepared to push his attack vigorously, having his enemy between two fires. At this moment the news of the truce was received and the action ceased, *the Austrians not having the least idea that there was a Prussian force in their rear.* Thus it appears that the Prussian Commander drove back a large body of Austrians, established himself in rear of the main body, and had time to communicate the fact to his General, whilst the Officer Commanding the Austrian force had no intimation of what had happened!

In minor affairs, the same want of organization is visible.

When the Prussian Army was advancing after the Battle of Königgrätz, the *Times'* correspondent relates how the cavalry of the Prussian advanced guard came upon the rear guard of the Austrians near the frontier of Moravia:—"The Austrians were collecting together from all the different houses and farmyards; mounted men, filing out of barns and strawhouses, were tiding slowly towards their rendezvous in the market place; men who had not yet mounted were leading their horses, strolling carelessly alongside them, when, by some fault of their sentinels, they were surprised by the Prussians."

The *Times'* military correspondent with the Austrian Army gives the following account of the march of the Austrian Army from Olmütz:—"On the 15th, the 8th Corps, and Benedek himself with his Staff, followed the course taken by the 2nd and 4th Corps on the previous day. The Prussians were known to be in the neighbourhood, and the orders were that this small army was to hold itself prepared to meet the enemy at any point along the route, that he might select for an attack. How this order was carried out I leave your military readers to judge from what follows. In front of the column was half a regiment of Lancers, then a brigade of Infantry; after that came four batteries of artillery of reserve, their train, and finally the bulk of the corps; the other half regiment of Lancers bringing up the rear. One of the most obvious precautions in marching through a country where the enemy may be expected to appear, is to throw out Cavalry patrols and Infantry skirmishers on both flanks to give timely notice of an enemy's advance; but this important duty appears to have been neglected, or only half executed, for the Brigade Weber, which marched on the right flank of the column, was too far to the rear, and the Cavalry division of Prince Taxis marched from Olmütz at 8 a.m., three hours after the Infantry, and did not come up until too late to be of any service. This was no fault of the Cavalry leader, for he only obeyed orders; Benedek and his Staff rode near the guns."

The result of this was that the column was attacked by the Prussians, and the Austrian Commander-in-Chief nearly captured.

In almost every instance in which we get an insight into the Austrian movements, some want of organization, similar to the cases mentioned, is discernible.

The Austrian fortresses appear to have exercised little influence on the campaign, and it will be interesting to endeavour to trace the cause.

Brialmont, in his "Défense des États," has entered fully into the strategical value of fortresses, and the considerations which should govern the choice of their positions.

The opinion which at one time prevailed on the subject was that a frontier should be defended by a triple row of fortresses, a day's march (15 to 18 miles) from each other, and arranged chequerwise at intervals also of a day's march; but some of the highest military authorities, Napoleon, Jomini, Marmont, Vauban, Turenne, Saxe, Paixhans, and others, have shewn that this is a very erroneous idea.

The multiplication of fortresses paralyses a large part of the forces of the kingdom, who have to be shut up in them as garrisons, and diminishes materially the number available for offensive operations. In modern wars also the size of armies has so materially increased that the commanders can afford to disregard fortresses, and without materially diminishing their numbers, to detach sufficient men to mask them without undergoing the trouble and delay of a siege. The number of roads, railroads, bridges, and other facilities for communication, has also so much increased that it is no longer possible to block up every approach, and fortresses must now be regarded not so much as barriers, as strategic points to facilitate the manœuvres of armies. General Paixhans has given the following remarkable proof of the diminution in the value of fortresses. Before 1741 there were more sieges than battles; from 1741 to 1783 there were 67 sieges to 100 battles; during the French Revolution 26 sieges to 100 battles; under the Consulate 23, and under the Empire only 16 to 100. It may be added to this that in 1859 and in 1866, there were no sieges. In the former year it is true that had the war been prolonged a siege would have been inevitable, but it would have been that of part of the intrenched camp formed by the quadrilateral which comes under a different category to an ordinary fortress.

Napoleon says on the subject of fortresses:—"Il en est des places fortes comme des placements de troupes. Prétendez-vous défendre une frontière par un cordon? vous êtes faible partout, car enfin tout ce qui est humain, bons officiers, bons généraux, tout cela n'est pas infini, et si vous êtes obligé de disséminer partout vous n'êtes fort nul part."

Instead therefore of disseminating fortresses over a line of frontier, the opinion is now generally accepted that they should be placed only where they can assist the strategic movements of troops. For this purpose there should be a great central fortress which may be placed surrounding the capital, unless the situation of the latter is very unfavourable in a strategic point of view. Between this central fortress and the frontier there should be a zone of fortresses on the principal lines of approach, and along the frontier there should be a zone of small fortresses guarding the principal strategic points such as defiles, bridges, &c. The fortresses of the central zone should be of such a nature as to be able to shelter the whole manœuvring army. Those of the outer line should be much smaller, their business being only to obstruct the entry of an army into the

country. The central fortress should be of the nature of a large entrenched camp. In addition to these, the principal sources of supply of the kingdom, such as dockyards, arsenals, the capital, &c., should be fortified, and also important strategical points such as bridges over wide rivers, &c.

It is very essential that the capital should be fortified, otherwise the movements of the field army are cramped by the necessity of providing for its safety. The capital being generally the centre of all the organization of the kingdom, the possession of it paralyses all operations, and history shews that few governments will subject themselves to the possibility of its capture. The campaign now under discussion seems to afford an additional illustration of this principle.

Brialmont has formularized the conditions that should govern the positions of fortresses as follows:—

1st. To occupy the principal defiles, such as gorges of mountains, junctions of valleys, roads traversing a forest or a marsh, also bridges intended to facilitate the operations of the defensive army on both banks of an important river.

2nd. To fortify the principal harbours, anchorages, and favourable points of disembarkation.

3rd. To construct at the limit of each zone of invasion a place intended to serve as a depôt and base of operations for an army acting beyond the frontiers (such as Lille, Metz, and Strasburg, whose duty it is to support the operations of the French Army in Belgium, the Ardennes, and in Germany).

4. Behind the places guarding the defiles, to erect on each zone a great place of refuge occupying a strategical point of the first order (according to this France ought to have a great place of refuge at Soissons, behind the north frontier; at Langres, behind the north-east frontier; a third at Lyons, behind the east frontier; and a fourth at Auch, behind the secondary front of the Pyrennees).

5. In the centre of the country, to construct a great fortified position to serve as a "réduit de défense."

The Austrian fortresses towards the Prussian frontier are Olmütz, Josephstadt, Königgrätz, and Theresienstadt. Prague was formerly a fortress, but can now hardly be considered as such, and in the present campaign it surrendered without a blow.

Olmütz does not appear to fulfil badly the requirements of one of the central zone of fortresses, although it is perhaps a little too near the frontier. It was a second class fortress, but detached forts have been erected on the surrounding heights which render it capable of sheltering a manœuvring army. Benedek, when defeated at Königgrätz, collected his shattered forces there, expecting probably that the Prussians would not dare to advance on the capital whilst he held that position on their flank and threatened their communications. How then was it that his expectations were not realized? *The capital was not fortified.* The Prussian Army, neglecting Benedek, advanced straight on Vienna, and the Austrian Army was obliged to retire by forced marches from Olmütz to assist in the defence of that city. This seems therefore to add another illustration to the principle that the capital should be always fortified.

The fortresses of Königgrätz and Josephstadt appear to fulfil the conditions neither of the outer nor central zone of fortresses. They are not sufficiently near to the frontier to guard the passes, and they are not of sufficient size to shelter the manœuvring army. Accordingly we find that they played a very unimportant part in the campaign. They were neither able to retard the advance

of the Prussians over the mountains, nor after the defeat of Königgrätz were they of any use to the defeated Austrian Army.

The fortress of Theresienstadt was not on the line of operations.

In one important particular, however, the three last-named fortresses rendered great service to the Austrians. They blocked the lines of railroad and prevented the Prussians from making use of them, though even this service was not effectually performed.

There are three lines, the possession of which would have been of great use to the Prussians in their advance; that from Dresden, by Theresienstadt, Prague, Pardubitz, Brünn to Vienna; that by Zittau, Arnau, Josephstadt (with a branch from the latter place by Trautenau), Königgrätz joining the first line at Pardubitz; a branch from the latter line at Turnau to Prague. The first line was useless to the Prussians, being blocked by the fortress of Theresienstadt and by the Saxon fort of Königstein. The second was also unavailable, being blocked by Josephstadt and Königgrätz. The third was not open when the war broke out, but was apparently sufficiently advanced to be available for the transport of supplies and was the only one which the Prussians were able to use. After the truce was concluded, the garrison of Theresienstadt, apparently in ignorance of it, sallied out and destroyed this line at its junction with the Dresden-Prague line, causing, as is stated by the *Times'* correspondent, great inconvenience to the Prussians, although active operations were no longer in progress.

There is no doubt that it is of material advantage to have a fortress "à cheval" of every line of railroad so as to render it of no service to the enemy. A railroad differs materially from a common road in this, that a break in the use of it neutralizes to a great extent its advantage. In the case of a common road intercepted by a fortress, if a corps of observation is placed so as to prevent the sallies of the garrison, or if each supply train is guarded by a sufficient convoy, the supplies can generally be carried by cross roads round the place without much hindrance to the traffic, but in the case of a railroad, it will not generally be possible to construct a line of rails round the fortress, the goods consequently have to be shifted into carts, carried round, and replaced in trucks on the other side, and the advantage of the railroad is to a great extent neutralized. It may be said that the enemy can always render a railroad useless when forced to retreat, by blowing up a bridge or by destroying a tunnel, &c., and that this would be equally effectual with a fortress placed à cheval across the line, but, practically, the enemy will generally be loth, unless in very desperate circumstances, to take a step so detrimental to the country, and which would render the railroad useless to him if he should be in a position again to advance; he will at all events defer it until the last moment, and there will be always the danger of the demolition being ineffectually or not carried out, as was the case with the bridge over the Turbigo, before the battle of Magenta; and in this last campaign, when the Austrians failed, until after the truce was concluded, to destroy a bridge which would have prevented the Prussians from making use of the line from Prague to Turnau, the only one that remained open to them in their advance.

Josephstadt being at the junction of the Zittau and Trautenau railroads, is well placed to defend them, and if the fortress of Prague was restored, it would effectually bar the two remaining lines. Prague also would be in a favourable